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(71) Applicant *(for all designated States except US)*: FRAUNHNOFER-GESELLSCHAFT ZUR FÖRDERUNG DER ANGEWAND TEN FORSCHUNG E.V. [DE/DE]; Leonrodstrasse 54, D–80636 München (DE).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: EBERLEIN, Ernst [DE/DE]; Waldstrasse 28 b, D–91091 Großenseebach (DE). BADRI, Sabah [MA/DE]; Sebaldusstrasse 8, D–91058 Erlangen (DE). LIPP, Stefan [DE/DE]; Steinweg 9 a, D–91058 Erlangen (DE). BUCHHOLZ, Stephan [DE/DE]; Kerschlacher Strasse 8, D–81447 München (DE). HEUBERGER, Albert [DE/DE]; Hausäckerweg 18, D–91056 Erlangen (DE). GERHÄUSER, Heinz [DE/DE]; Saugendorf 17, D–91344 Waischenfeld (DE).

(74) Agent: SCHOPPE, Fritz; Schoppe & Zimmermann, Postfach 71 08 67, D–81458 München (DE).

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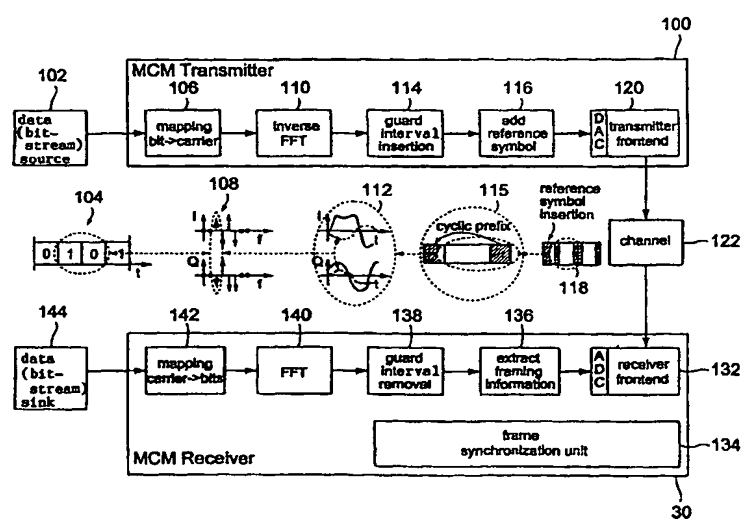

(57) Abstract

A method for generating a signal having a frame structure, each frame of the frame structure comprising at least one useful symbol (12), a guard interval (14) associated to the at least one useful symbol (12) and a reference symbol (16), comprises the step of performing an amplitude modulation of a bit sequence such that the envelope of the amplitude modulated bit sequence defines a reference pattern of the reference symbol (16). A method for frame synchronization of a signal having such a frame structure comprises the steps of receiving the signal, down–converting the received signal, performing (164) an amplitude–demodulation of the down–converted signal in order to generate an envelope, correlating (166) the envelope with a predetermined reference pattern in order to detect a signal reference pattern of the reference symbol (16) in the signal, and performing the frame synchronization based on the detection of the signal reference pattern.

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COARSE FREQUENCY SYNCHRONISATION IN MULTICARRIER SYSTEMS

FIELD OF THE INVENTION

The present invention relates to methods and apparatus for generating a signal having a frame structure, wherein each frame of the frame structure is composed of useful symbols, a guard interval associated to each useful symbol and one reference symbol. In addition, the present invention relates to methods and apparatus for frame synchronization of signals having the above structure.

The present invention is particularly useful in a MCM transmission system (MCM = Multi-carrier modulation) using an orthogonal frequency division multiplexing (OFDM) for digital broadcasting.

BACKGROUND OF THE INVENTION

In a MCM (OFDM) transmission system the binary information is represented in the form of a complex spectrum, i.e. a distinct number of complex subcarrier symbols in the frequency domain. In the modulator a bitstream is represented by a sequence of spectra. Using an inverse Fourier-transform (IFFT) a MCM time domain signal is produced from this sequence of spectra.

In case of a transmission of this described MCM signal via a multipath channel with memory, intersymbol interference (ISI) occurs due to multipath dispersion. To avoid ISI a guard interval of fixed length is added between adjacent MCM symbols in time. The guard interval is chosen as cyclic prefix. This means that the last part of a time domain MCM symbol is placed in front of the symbol to get a periodic extension. If the fixed length of the chosen guard interval is greater than the maximum multipath delay, ISI will not occur.

In the receiver the information which is in the frequency and time domain (MCM) has to be recovered from the MCM time domain signal. This is performed in two steps. Firstly, optimally locating the FFT window, thus eliminating the guard interval in front of each MCM time domain symbol. Secondly, performing a Fourier Transform of the sequence of useful time samples thus obtained.

As a result a sequence of spectral symbols is thus recovered. Each of the symbols contains a distinct number of information carrying subcarrier symbols. Out of these, the information bits are recovered using the inverse process of the modulator.

Performing the above described method, the following problem occurs in the receiver. The exact position of the guard interval and hence the position of the original useful parts of the time domain MCM symbols is generally unknown. Extraction of the guard interval and the subsequent FFT-transform of the resulting useful part of the time signal is not possible without additional information. To provide this additional information, a known (single carrier) sequence in the form of a (time domain) reference symbol is inserted into the time signal. With the knowledge about the positions of the reference symbols in the received signal, the exact positions of the guard intervals and thus the interesting information carrying time samples are known.

The periodical insertion of the reference symbol results in a frame structure of the MCM signal. This frame structure of a MCM signal is shown in Figure 1. One frame of the MCM signal is composed of a plurality of MCM symbols 10. Each MCM symbol 10 is formed by an useful symbol 12 and a guard interval 14 associated therewith. As shown in Figure 1, each frame comprises one reference symbol 16.

A functioning synchronization in the receiver, i.e. frame, frequency, phase, guard interval synchronization is necessary for the subsequent MCM demodulation. Consequently, the first

and most important task of the base band processing in the receiver is to find and synchronize to the reference symbol.

DESCRIPTION OF THE PRIOR ART

Most prior art methods for frame synchronization have been developed for single carrier transmission over the AWGN channel (AWGN = Additive White Gaussian Noise). These prior art methods based on correlation are, without major changes, not applicable for transmission over multipath fading channels with large frequency offsets or MCM transmission systems that use, for example, an orthogonal frequency division multiplexing.

For MCM transmission systems particular frame synchronization methods have been developed.

Warner, W.D., Leung C.: OFDM/FM Frame Synchronization for Mobile Radio Data Communication, IEEE Trans. On Vehicular Technology, vol. VT-42, August 1993, pp. 302 to 313, teaches the insertion of reference symbols in the form of tones in parallel with the data into the MCM symbol. The reference symbols occupy several carriers of the MCM signal. In the receiver, the synchronization carriers are extracted in the frequency domain, after a FFT transform (FFT = fast Fourier transform) using a correlation detector. In the presence of large frequency offsets, this algorithm becomes very complex because several correlators must be implemented in parallel.

A further prior art technique is to insert a periodic reference symbol into the modulated MCM signal. This reference symbol is a CAZAC sequence (CAZAC = Constant Amplitude Zero Autocorrelation). Such techniques are taught by: Classen, F., Meyr, H.: Synchronization algorithms for an OFDM system for mobile communication, in *Codierung für Codierung für Quelle, Kanal und Übertragung*: ITG-Fachbericht 130, pp. 105-114, München, October 1994, ITG, VDE-Verlag, Berlin Offenbach; Lambrette, U., Horstmannshoff, J., Meyr, H.: Techniques for Frame Synchronization on Unknown Frequency Selective Channels, *Proc.*

Vehic. Technology Conference, 1997; Schmidl, T.M., Cox, D.C.: Low-Overhead, Low-Complexity [Burst] Synchronization for OFDM Transmission, *Proc. IEEE Int. Conf. on Commun.*, 1996. In such systems, the receiver's processor looks for a periodic repetition. For these algorithms coarse frequency synchronization has to be achieved prior to or at least simultaneously with frame synchronization.

Van de Beek, J, Sandell, M., Isaksson, M, Börjesson, P.: Low-Complex Frame Synchronization in OFDM Systems, *Proc. of the ICUPC*, 1995, avoid the insertion of additional reference symbols or pilot carriers and use instead the periodicity in the MCM signal which is inherent in the guard interval and the associated cyclical extension. This method is suitable only for slowly varying fading channels and small frequency offsets.

US-A-5,191,576 relates to a method for the diffusion of digital data designed to be received notably by mobile receivers moving in an urban environment. In this method, the header of each frame of a broadcast signal having a frame structure has a first empty synchronization symbol and a second unmodulated wobbled signal forming a two-stage analog synchronization system. The recovery of the synchronization signal is achieved in an analog way, without prior extraction of a clock signal at the binary level.

The methods for frame synchronization available up to date require either prior achieved frequency synchronization or become very complex when the signal in the receiver is corrupted by a large frequency offset.

If there is a frequency offset in the receiver, as can easily be the case when a receiver is powered-on and the frequency synchronization loop is not yet locked, problems will occur. When performing a simple correlation there will only be noise at the output of the correlator , i.e. no maximum can be found if the frequency offset exceeds a certain bound. The size of the frequency offset depends on the length (time) of the correlation to be performed, i.e. the longer it takes, the

smaller the allowed frequency offset becomes. In general, frequency offset increases implementation complexity.

Frequency offsets occur after power-on or later due to frequency deviation of the oscillators used for down-conversion to baseband. Typical accuracies for the frequency of a free running local oscillator (LO) are at ±50 ppm of the carrier frequency. With a carrier frequency in S-band (e.g. 2.34 GHz) there will be a maximum LO frequency deviation of above 100 kHz (117.25 kHz). A deviation of this magnitude puts high demands on the above methods.

In the case of multipath impaired transmission channel, a correlation method yields several correlation maxima in addition to the distinct maximum for an AWGN channel. The best possible frame header position, i.e. the reference symbol, has to be selected to cope with this number of maxima. In multipath channels, frame synchronization methods with correlations can not be used without major changes. Moreover, it is not possible to use data demodulated from the MCM system, because the demodulation is based on the knowledge of the position of the guard interval and the useful part of the MCM symbol.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method and an apparatus for generating a signal having a frame structure that allow a frame synchronization after the signals have been transmitted even in the case of a carrier frequency offset or in the case of a transmission via a multipath fading channel.

It is a further object of the present invention to provide a method and an apparatus for frame synchronization of a signal having a frame structure even in the case of a carrier frequency offset.

In accordance with a first aspect, the present invention

provides a method for generating a signal having a frame structure, each frame of the frame structure comprising at least one useful symbol, a guard interval associated to the at least one useful symbol and a reference symbol, the method comprising the step of performing an amplitude modulation of a bit sequence such that the envelope of the amplitude modulated bit sequence defines a reference pattern of the reference symbol.

In accordance with a second aspect, the present invention provides a method for generating a multi-carrier modulated signal having a frame structure, each frame of the frame structure comprising at least one useful symbol, a guard interval associated to the at least one useful symbol and a reference symbol, the method comprising the steps of:

providing a bitstream;

mapping bits of the bitstream to carriers in order to provide a sequence of spectra;

performing an inverse Fourier transform in order to provide multi-carrier modulated symbols;

associating a guard interval to each multi-carrier modulated symbol;

generating the reference symbol by performing an amplitude modulation of a bit sequence such that the envelope of the amplitude modulated bit sequence defines a reference pattern of the reference symbol; and

associating the reference symbol to a predetermined number of multi-carrier modulated symbols and associated guard intervals in order to define the frame.

In accordance with a third aspect, the present invention provides a method for frame synchronization of a signal having a frame structure, each frame of the frame structure comprising

at least one useful symbol, a guard interval associated with the at least one useful symbol and a reference symbol, the method comprising the steps of:

receiving the signal;

down-converting the received signal;

performing an amplitude-demodulation of the down-converted signal in order to generate an envelope;

correlating the envelope with a predetermined reference pattern in order to detect a signal reference pattern of the reference symbol in the signal; and

performing the frame synchronization based on the detection of the signal reference pattern.

In accordance with a fourth aspect, the present invention provides a method for frame synchronization of a multi-carrier modulated signal having frame structure, each frame of the frame structure comprising at least one useful symbol, a guard interval associated to the at least one useful symbol and a reference symbol, the method comprising the steps of:

receiving the multi-carrier modulated signal;

down-converting the received multi-carrier modulated signal;

performing an amplitude-demodulation of the down-converted multi-carrier modulated signal in order to generate an envelope;

correlating the envelope with a predetermined reference pattern in order to detect a signal reference pattern of the reference symbol in the multi-carrier modulated signal;

performing the frame synchronization based on the detection

of the signal reference pattern;

extracting the reference symbol and the at least one guard interval from the down-converted received multi-carrier modulated signal based on the frame synchronization;

performing a Fourier transform in order to provide a sequence of spectra from the at least one useful symbol;

de-mapping the sequence of spectra in order to provide a bitstream.

In accordance with a fifth aspect, the present invention provides an apparatus for generating a signal having a frame structure, each frame of the frame structure comprising at least one useful symbol, a guard interval associated to the at least one useful symbol and a reference symbol, the apparatus comprising an amplitude modulator for performing an amplitude modulation of a bit sequence such that the envelope of the amplitude modulated bit sequence defines a reference pattern of the reference symbol.

In accordance with a sixth aspect, the present invention provides an apparatus for generating a multi-carrier modulated signal having a frame structure, each frame of the frame structure comprising at least one useful symbol, a guard interval associated to the at least one useful symbol and a reference symbol, the apparatus comprising:

means for providing a bitstream;

means for mapping bits of the bitstream to carriers in order to provide a sequence of spectra;

means for performing an inverse Fourier transform in order to provide multi-carrier modulated symbols;

means for associating a guard interval to each multi-carrier modulated symbol;

means for generating the reference symbol by an amplitude modulator for performing an amplitude modulation of a bit sequence such that the envelope of the amplitude modulated bit sequence defines a reference pattern of the reference symbol; and

means for associating the reference symbol to a predetermined number of multi-carrier modulated symbols and associated guard intervals in order to define the frame.

In accordance with a seventh aspect, the present invention provides an apparatus for frame synchronization of a signal having a frame structure, each frame of the frame structure comprising at least one useful symbol, a guard interval associated to the at least one useful symbol and a reference symbol, the apparatus comprising:

receiving means for receiving the signal;

a down-converter for down-converting the received signal;

an amplitude-demodulator for performing an amplitude demodulation of the down-converted signal in order to generate an envelope;

a correlator for correlating the envelope with a predetermined reference pattern in order to detect a signal reference pattern of the reference symbol in the signal; and

means for performing the frame synchronization based on the detection of the signal reference pattern.

In accordance with a eighth aspect, the present invention provides an apparatus for frame synchronization of a multi-carrier modulated signal having a frame structure, each frame of the frame structure comprising at least one useful symbol, a guard interval associated to the at least one useful

symbol and a reference symbol, the apparatus comprising:

a receiver for receiving the multi-carrier modulated signal;

a down-converter for down-converting the received multi-carrier modulated signal;

an amplitude-demodulator for performing an amplitude-demodulation of the down-converted multi-carrier modulated signal in order to generate an envelope;

a correlator for correlating the envelope with a predetermined reference pattern in order to detect a signal reference pattern of the reference symbol in the multi-carrier modulated signal;

means for performing the frame synchronization based on the detection of the signal reference pattern;

means for extracting the reference symbol and the at least one guard interval from the down-converted received multi-carrier modulated signal based on the frame synchronization in order to generate the at least one useful symbol;

means for performing a Fourier transform in order to provide a sequence of spectra from the at least one useful symbol; and

means for de-mapping the sequence of spectra in order to provide a bitstream.

The present invention provides a novel structure of the reference symbol along with a method to determine the position of the reference symbol and thus the start of a frame in a signal having a frame structure as shown for example in Figure 1.

The invention relates to a method for finding frame headers independently of other synchronization information and thus for positioning the FFT windows correctly. This includes the extraction of a guard interval. The method is based on the detection of a known reference symbol of the frame header in the reception signal, e.g. in the digital complex baseband. The new frame synchronization will be performed as the first synchronization task.

Synchronization to the reference symbol, i.e. the frame header is the first step to initiate radio reception. The reference symbol is structured to accomplish this. The information contained in the reference symbol must therefore be independent of other synchronization parameters, e.g. frequency offset. For this reason, in accordance with the present invention, the form of the reference symbol selected is an amplitude modulated sequence (AM sequence) in the complex baseband. Thus, the information contained in the reference symbol is only that given in the amplitude and not that in the phase. Note that the phase information will be corrupted by a possible frequency offset. In preferred embodiments of the present invention, the AM information is constructed from a bit sequence with special features. The information sequence is selected in a way which makes it easy and secure to find it in the time domain. A bit sequence with good autocorrelation properties is chosen. Good autocorrelation properties means a distinct correlation maximum in a correlation signal which should be as white as possible.

A pseudo random bit sequence (PRBS) having good autocorrelation properties meets the above requirements.

Using the envelope of the signal to carry bit information offers additional flexibility. First it has to be decided which envelope values should correspond to the binary values of 0 and 1. The parameters are mean amplitude and modulation rate. Attention should be paid to selecting the mean amplitude of the reference symbol (performance) identically to the mean amplitude of the rest of the frame. This is due to the amplitude normalization (AGC; AGC = Automatic Gain Control)

performed in the receiver. It is also possible to select the mean amplitude of the reference symbol higher than the mean signal amplitude, but then care has to be taken that the time constant of the AGC (1/sensitivity) is selected high enough to secure that the strong (boosted) signal of the reference symbol does not influence the AGC control signal and thus attenuate the signal following the reference symbol.

Another degree of freedom can be characterized as modulation degree d. This parameter is responsible for the information density of the modulating signal mod(t) formed out of the binary sequence bin(t) as follows: mod(t) = bin(t/d). This modulation degree can be chosen as free parameter fixed by an integer or real relation to the sampling rate. It is appropriate to choose the modulation degree d as an integer value because of the discrete values of the binary sequence:

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d = 1: mod(m) = bin(m)
d = 2: mod(m) = bin(m/2)          for m even
              = bin_int(m/2)      for m odd
d = 3: mod(m) = bin(m/3)          for m = 0, ±3, ±6, ±9, ...
                bin_int(m/3)      else
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The signal values bin_int(m/d) are computed from the binary sequence bin(m) by ideal interpolation (between the discrete integer values m) with the factor of d. This is similar to an ideal sampling rate expansion (with sin(x)/x interpolation), but the sampling rate remains, only less bits of the binary sequence bin(m) correspond to the resulting interpolated sequence mod(m). This parameter m indicates the discrete time.

With increasing m the modulating signal mod(t) is expanded in time relative to the basic binary sequence, this results in a bandwidth compression of the resulting AM spectrum with regard to the basic binary sequence. A time expansion by a factor 2 results in a bandwidth compression by the same factor 2. In addition to the bandwidth compression, a further advantage of a higher modulation degree d is a reduced complexity of the search method in the receiver due to the fact that only each

d^{th} sample has a corresponding binary value. Choosing the factor d = 1 is not preferred since this would result in aliasing due to disregard of the sampling theorem. For this reason, in a preferred embodiment of the present invention d is chosen to be 2.

The choice of length and repetition rate of the reference symbol is, on the one hand, dominated by the channel properties, e.g. the channel's coherence time. On the other hand the choice depends on the receiver requirements concerning mean time for initial synchronization and mean time for resynchronization after synchronization loss due to a channel fade.

In the receiver, the first step after the down-conversion of the received signal is to perform an amplitude-demodulation of the down-converted signal in order to generate an envelope, i.e. in order to determine the amplitude of the signal. This envelope is correlated with a replica reference pattern in order to detect the signal reference pattern of the reference symbol in the signal. In the case of a AWGN channel, the result of this correlation will be a white noise signal with zero mean value and with a clearly visible (positive) maximum. In the case of a multipath channel, several maxima will occur in the correlation signal computed by this correlation. In the former case, the location of the reference symbol is determined based on the signal maximum, whereas in the latter case a weighting procedure is performed in order to find out the maximum corresponding to the location of the reference symbol.

Thus, the present invention shows how to find a reference symbol by a detection method which is simple. Furthermore, the present invention can be used for one-carrier or multi-carrier systems. The present invention is particularly useful in multi-carrier modulation systems using an orthogonal frequency division multiplexing, for example in the field of digital broadcasting. The synchronization methods according to the present invention are independent of other synchronization steps. Since the information needed for the synchronization is

contained in the envelope of the preamble, i.e. the reference symbol, the reference symbol is independent of possible frequency offsets. Thus, a derivation of the correct down sampling timing and the correct positioning of the FFT window can be achieved. The reference symbol of the present invention can be detected even if the frequency synchronization loop is not yet locked or even in the case of a carrier frequency offset. The frame synchronization method in accordance with the present invention is preferably performed prior to other and without knowledge of other synchronization efforts.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following, preferred embodiments of the present invention will be explained in detail on the basis of the drawings enclosed, in which:

Figure 1 shows a schematic view of a signal having a frame structure;

Figure 2 shows a block diagram of a MCM system to which the present invention can be applied;

Figure 3 shows a schematic block diagram of a frame and frequency synchronization system in a MCM receiver;

Figure 4 shows a schematic diagram of an apparatus for frame synchronization; and

Figure 5 shows a typical channel impulse response of a single frequency network in S-band.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Although the present invention is explained mainly referring to a MCM system, it is obvious that the present invention can be used in connection with different signal transmissions that are

based on different kinds of modulation.

Figure 2 shows a MCM system overview on the basis of which the present invention will be described in detail. At 100 a MCM transmitter is shown that substantially corresponds to a prior art MCM transmitter except for the kind of the reference symbol being added to each frame of a MCM signal. A description of such a MCM transmitter can be found, for example, in William Y. Zou, Yiyan Wu, "COFDM: AN OVERVIEW", IEEE Transactions on Broadcasting, vol. 41, No. 1, March 1995.

A data source 102 provides a serial bitstream 104 to the MCM transmitter. The incoming serial bitstream 104 is applied to a bit-carrier mapper 106 which produces a sequence of spectra 108 from the incoming serial bitstream 104. An inverse fast Fourier transform (FFT) 110 is performed on the sequence of spectra 108 in order to produce a MCM time domain signal 112. The MCM time domain signal forms the useful MCM symbol of the MCM time signal. To avoid intersymbol interference (ISI) caused by multipath distortion, a unit 114 is provided for inserting a guard interval of fixed length between adjacent MCM symbols in time. In accordance with a preferred embodiment of the present invention, the last part of the useful MCM symbol is used as the guard interval by placing same in front of the useful symbol. The resulting MCM symbol is shown at 115 in Figure 2 and corresponds to the MCM symbol 10 depicted in Figure 1.

In order to obtain the final frame structure shown in Figure 1, a unit 116 for adding a reference symbol for each predetermined number of MCM symbols is provided.

In accordance with the present invention, the reference symbol is an amplitude modulated bit sequence. Thus, an amplitude modulation of a bit sequence is performed such that the envelope of the amplitude modulated bit sequence defines a reference pattern of the reference symbol. This reference pattern defined by the envelope of the amplitude modulated bit sequence has to be detected when receiving the MCM signal at a MCM receiver. In a preferred embodiment of the present

invention, a pseudo random bit sequence having good auto-correlation properties is used as the bit sequence for the amplitude modulation.

The choice of length and repetition rate of the reference symbol depends on the properties of the channel through which the MCM signal is transmitted, e.g. the coherence time of the channel. In addition, the repetition rate and the length of the reference symbol, in other words the number of useful symbols in each frame, depends on the receiver requirements concerning mean time for initial synchronization and mean time for resynchronization after synchronization loss due to a channel fade.

The resulting MCM signal having the structure shown at 118 in Figure 2 is applied to the transmitter front end 120. Roughly speaking, at the transmitter front end 120, a digital/analog conversion and an up-converting of the MCM signal is performed. Thereafter, the MCM signal is transmitted through a channel 122.

Following, the mode of operation of a MCM receiver 130 is shortly described referring to Figure 2. The MCM signal is received at the receiver front end 132. In the receiver front end 132, the MCM signal is down-converted and, furthermore, a analog/digital conversion of the down-converted signal is performed. The down-converted MCM signal is provided to a frame synchronization unit 134. The frame synchronization unit 134 determines the location of the reference symbol in the MCM symbol. Based on the determination of the frame synchronization unit 134, a reference symbol extracting unit 136 extracts the framing information, i.e. the reference symbol, from the MCM symbol coming from the receiver front end 132. After the extraction of the reference symbol, the MCM signal is applied to a guard interval removal unit 138. The mode of operation of the frame synchronization unit 134 which represents the present invention will be described in detail referring to Figures 3 and 4 hereinafter.

The result of the signal processing performed hereherto in the MCM receiver is the useful MCM symbols.

The useful MCM symbols output from the guard interval removal unit 138 are provided to a fast Fourier transform unit 140 in order to provide a sequence of spectra from the useful symbols. Thereafter, the sequence of spectra is provided to a carrier-bit mapper 142 in which the serial bitstream is recovered. This serial bitstream is provided to a data sink 144.

Following, the mode of operation of the frame synchronization unit will be described in detail referring to Figures 3 and 4. Figure 3 represents a further high level diagram of an apparatus for frame synchronization of a MCM signal. In the receiver front end 150, the incoming MCM signal is down-converted. In Figure 3, an analog/digital converter 152 is shown separated from the receiver front end 150. The output signal of the analog/digital converter 152 is applied to a frame synchronization unit 154. This frame synchronization unit 154 performs the frame synchronization in accordance with the present invention which will be described in detail referring to Figure 4 hereinafter. Depending on the frame synchronization of the frame synchronization unit 154, a MCM demodulator 156 demodulates the MCM signal in order to provide a demodulated serial bitstream.

As shown in Figure 3, the described reference symbol in accordance with the present invention can also be used for a coarse frequency synchronization of the MCM signal. Namely, the frame synchronization unit 154 also serves as a coarse frequency synchronization unit for determining a coarse frequency offset of the carrier frequence caused, for example, by a difference of the frequencies between the local oscillator of the transmitter and the local oscillator of the receiver. The determined frequency offset is used in order to perform a coarse frequency correction at a point 158.

In Figure 4, a detailed schematic of the frame synchronization in accordance with the present application is depicted. A MCM

signal transmitted through the channel 122 is received at the receiver RF-front end 150. The down-converted MCM signal is sampled at the receiver front end 150 and is, in the preferred embodiment, provided to a fast running automatic gain control (time constant < MCM symbol duration) in order to eliminate fast channel fluctuations (channel coherence time ≈ MCM symbol duration). The fast AGC 162 is used in addition to the normally slow AGC in the signal path, in the case of transmission over a multipath channel with long channel impulse response and frequency selective fading. The fast AGC adjusts the average amplitude range of the signal to the known average amplitude of the reference symbol. The so processed symbol is provided to an amplitude determining unit 164.

The amplitude determining unit 164 can use the simple $\text{alpha}_{\text{max}+}$ $\text{beta}_{\text{min}-}$ method in order to calculate the amplitude of the signal. This method is described for example in Palachels A.: DSP-mP Routine Computes Magnitude, EDN, October 26, 1989; and Adams, W. T., and Bradley, J.: Magnitude Approximations for Microprocessor Implementation, IEEE Micro, Vol. 3, No. 5, October 1983.

The output signal of the amplitude determining unit 164 is applied to a correlator 166. In the correlator 166, a cross correlation between the amplitude signal output from the amplitude determining unit 164 and a known ideal amplitude information is computed. The known ideal amplitude information is stored in the correlator. For both, the amplitude and the known ideal amplitude information, their amplitudes are symmetrically to zero relative to their average amplitude.

In the ideal AWGN case, the result will be a white noise signal with zero mean value and with a clearly visible positive maximum. In this ideal AWGN case, the position of the single maximum is evaluated in a maximum position unit 172. On the basis of this evaluation, the reference symbol and the guard intervals are extracted from the MCM signal in a combined reference symbol/guard extraction unit 136/138. Although these units are shown as a combined unit 136/138 in Figure 4, it is

clear that separate units can be provided. The MCM signal is transmitted from the RF front end 150 to the reference symbol/guard extraction unit 136/138 via a low pass filter 174.

In the case of time spreading encountered in a multipath channel, several maxima corresponding to the number of clusters in the channel impulse response occur in the output signal of the correlator. A schematic view of three such clusters located in a time window of maximum about 60 microseconds is shown in Figure 5. Out of the several maxima caused by the time spreading encountered in a multipath channel, the best one has to be selected as the position of the frame header, i.e. the reference symbol. Therefore, a threshold unit 168 and a weighting unit 170 are provided between the correlator 166 and the maximum position unit 172. The threshold unit 168 is provided to remove maxima having an amplitude below a predetermined threshold. The weighting unit 164 is provided in order to perform a weighting procedure on the remaining maxima such that the maximum corresponding to the reference symbol can be determined. An examplary weighting procedure performed in the weighting unit 170 is as follows.

The first significant maximum is considered to be the best one. The output signal of the correlator is observed from the first detected maximum onwards for the maximum length of the channel impulse response and an amplitude weighting function is applied to the signal. Because the actual channel impulse response length is unknown, the following fact can be remembered. During system design, the length of the channel impulse response has to be investigated. In a MCM system, the guard interval shall be equal or longer than the maximum expected channel impulse response. For this reason, the part (interval with l_I samples, l_I corresponding to the maximum expected channel impulse response, i.e. the guard interval length) of the correlation output signal starting with the first maximum,

$$I(k_0) = \sum_{n=0}^{l_I-1} r(k_0+n) \qquad \text{(Eq.1)}$$

with k_0 being the position of the first maximum, will be

examined to find the best frame start position. The above signal part is weighted with the function

$$W(n) = 10^{\frac{weight\_dB}{10} \cdot \frac{n}{l_I - 1}} \qquad \text{(Eq.2)}$$

The position (n_{max}) of the maximum in the resulting signal interval

$$I_{weighted}(k_0) = \sum_{n=0}^{l_I-1}\left[r(k_0+n)W(n)\right] = \sum_{n=0}^{l_I-1}\left[r(k_0+n)\,10^{\frac{weight\_dB}{10} \cdot \frac{n}{l_I-1}}\right] \qquad \text{(Eq.3)}$$

will be chosen as best frame start position.

r(k) designates the output signal of the correlator (166) at the time k. The signal is present with a clock frequency which is determined by the multiplication: oversampling factor * subcarrier symbol frequency. The parameter k designates the discrete time in sample clocks. This signal is windowed with information from the threshold unit 168. An interval having the length of l_I values is extracted from the signal r(k). The first value being written into the interval is the correlation start value at the time k_0, at which the output value $r(k_0)$ exceeds the threshold value of the threshold unit 168 for the first time. The interval with the windowed signal is designated by the term $I(k_0)$. The parameter n designates the relative time, i.e. position, of a value inside the interval.

Using the described weighting operation, the earlier correlation maxima are more likely to be chosen as right frame start position. A later coming maximum will only be chosen as frame start position, if the value of the maximum is significantly higher than the earlier one. This operation is applicable especially for MCM, because here it is better to detect the frame start positions some samples too early than some samples too late. Positioning the frame start some samples too early leads to positioning the FFT window a little bit into the guard interval, this contains information of the same MCM symbol and therefore leads to little effects. If the frame start position is detected some samples too late, then the FFT window includes some samples of the following guard interval.

This leads to a more visible degradation, because the following guard interval contains information of the following MCM symbol (ISI occurs).

It is important to know that the first visible correlation maximum after receiver power-on does not necessarily correspond to the first CIR cluster. It is possible that it is corresponding to a later cluster, see Figure 5. For this reason during power-on one should wait for a second frame start before starting demodulation.

It is clear that amplitude determining methods different from the described alpha_{max+} beta_{min-} method can be used. For simplification, it is possible to reduce the amplitude calculation to a detection as to whether the current amplitude is above or below the average amplitude. The output signal then consists of a -1/+1 sequence which will be correlated with a known bit sequence, also in -1/+1 values. This correlation can easily be performed using a simple integrated circuit (IC).

In addition, an oversampling of the signal received at the RF front end can be performed. For example, the received signal can be expressed with two times oversampling.

This oversampled signal is passed to a fast running AGC to eliminate fast channel fluctuations before the amplitude of the signal is calculated. The amplitude information will be hard quantized. Values larger than the mean amplitude, mean amplitude is 1, will be expressed as +1, values smaller than the mean amplitude will be expressed as -1. This -1/+1 signal is passed to the correlator that performs a cross correlation between the quantized signal and the stored ideal amplitude values of the reference symbol:

```
amp_sto(k) = 2*bin(k/4),
    if k = 2(oversampling factor) * 2(interpolation factor) *
    1,2,3...92
    (92 for 184 reference symbol and interpolation factor 2)
amp_sto(k)  =  0,  else,  k  <=  2(oversampling  factor)  *
```

2(interpolation factor) * 92
(first part of amp_sto = [0 0 0 -1 0 0 0 1 0 0 0 1 0 0 0 -1 0 .....]).

With this algorithm a correlation maximum of 92 is achievable.

Again, the maxima in the correlator output signal correspond to different frame start positions due to different multipath clusters. In this signal with various maxima the best frame start position has to be chosen. This is done in the following steps: The output of the correlator is given to a threshold detection. If the signal first time exceeds the threshold (a threshold of 50 has proved to be applicable) the best position search algorithm is initialized. The correlator output signal in the interval following the threshold exceeding value will be weighted with the weighting function, see above. The position of the resulting maximum in the weighted signal will be chosen as best frame start position. With the knowledge about the best frame start position the guard interval extraction and the following MCM demodulation will be performed.

Some more efforts can be carried out to increase frame synchronization accuracy. These methods will be explained in the following.

A postprocessing of the frame start decision is performed in order a) to increase the reliability of the frame synchronization; b) to secure that no frame start position is disregarded; and c) to optimize the frame start position in case of varying CIR cluster positions.

Using information of other frame start positions. It is known that in front of each frame a reference symbol is inserted into the signal. If the position of the currently detected frame start has changed significantly regarding the last detected frame start, demodulation of the two frames in total and completely independent from each other is possible. It is also possible to buffer the last signal frame and to perform the required shift of the frame start position step by step with

the MCM symbols of the frame. This results in an interpolative positioning of the single MCM symbols including simultaneous asynchronous guard interval extraction for the different MCM symbols.

Such an interpolative positioning of the FFT window is also possible if one frame start position is missing, i. e. the frame start has not been detected. If one frame start position is missing the guard interval extraction can be performed the same way as in the frame before without large performance degradation. This is due to the normally only slowly varying CIR cluster positions, but only if the signal strength is good enough. Stopping demodulation and waiting for the next detected frame start position is also imaginable but not desirable because of the long interrupt.

What follows is an example of a reference symbol of 184 samples (subcarrier symbols) as provided by the inventive apparatus for generating a signal having a frame structure.

The underlying binary sequence of length 92 is:

```
bin = [0 1 1 0 1 1 0 1 0 1 1 0 1 0 1 0
       0 0 1 1 1 0 0 0 0 0 0 0 1 1 0
       1 1 1 1 1 0 0 0 1 1 1 0 0 0 0 0
       0 0 1 1 1 0 1 1 1 0 0 1 1 0 1 1
       1 0 1 1 0 1 0 1 0 1 1 0 1 1 0 1
       1 0 1 0 0 0 0 1 0 1 1 0]
```

The modulated binary sequence is:

```
i_q = [0.5 1.5 1.5 0.5 1.5 1.5 0.5 1.5 0.5 1.5 1.5 0.5 1.5 0.5
       1.5 0.5 0.5 0.5 1.5 1.5 1.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
       0.5 1.5 1.5 0.5 1.5 1.5 1.5 1.5 1.5 0.5 0.5 0.5 1.5 1.5
       1.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1.5 1.5 1.5 0.5 1.5 1.5
       1.5 0.5 0.5 1.5 1.5 0.5 1.5 1.5 1.5 0.5 1.5 1.5 0.5 1.5
       0.5 1.5 0.5 1.5 1.5 0.5 1.5 1.5 0.5 1.5 0.5 1.5 0.5 0.5
       0.5 0.5 1.5 0.5 1.5 1.5 0.5]
```

This modulated binary sequence i_q is interpolated in order to produce an interpolated sequence i_q_int:

```
i_q_int = [0.5000  1.0635  1.5000  1.7195  1.5000  0.8706  0.5000
           0.8571  1.5000  1.7917  1.5000  0.8108  0.5000  1.0392
           1.5000  1.0392  0.5000  0.8108  1.5000  1.7984  1.5000
           0.8108  0.5000  1.0460  1.5000  0.9997  0.5000  0.9603
           1.5000  1.1424  0.5000  0.3831  0.5000  0.4293  0.5000
           0.9997  1.5000  1.5769  1.5000  1.5769  1.5000  1.0065
           0.5000  0.3899  0.5000  0.5325  0.5000  0.4931  0.5000
           0.4999  0.5000  0.4931  0.5000  0.5325  0.5000  0.3967
           0.5000  0.9603  1.5000  1.7522  1.5000  0.8571  0.5000
           0.8965  1.5000  1.6422  1.5000  1.4669  1.5000  1.4737
           1.5000  1.6096  1.5000  0.9929  0.5000  0.4226  0.5000
           0.4226  0.5000  0.9997  1.5000  1.5769  1.5000  1.5769
           1.5000  1.0065  0.5000  0.3899  0.5000  0.5325  0.5000
           0.4931  0.5000  0.4931  0.5000  0.5325  0.5000  0.3899
           0.5000  1.0065  1.5000  1.5701  1.5000  1.6096  1.5000
           0.8965  0.5000  0.8965  1.5000  1.6096  1.5000  1.5633
           1.5000  1.0392  0.5000  0.2867  0.5000  0.9929  1.5000
           1.7454  1.5000  0.8571  0.5000  0.9033  1.5000  1.6028
           1.5000  1.6028  1.5000  0.9033  0.5000  0.8503  1.5000
           1.7917  1.5000  0.8108  0.5000  1.0460  1.5000  0.9929
           0.5000  0.9929  1.5000  1.0460  0.5000  0.8108  1.5000
           1.7917  1.5000  0.8571  0.5000  0.8571  1.5000  1.7849
           1.5000  0.8571  0.5000  0.8571  1.5000  1.7917  1.5000
           0.8176  0.5000  1.0065  1.5000  1.1424  0.5000  0.3436
           0.5000  0.5788  0.5000  0.3436  0.5000  1.1424  1.5000
           1.0065  0.8312  1.5000  1.7263  1.5000  1.0635  0.5000
           0.0637]
```

amp_int = i_q_int + j*i_q_int

amp_int is the reference symbol inserted periodically into the signal after the guard interval insertion.

As it is clear from the above specification, the present invention provides methods and apparatus for generating a signal having a frame structure and methods and apparatus for

frame synchronization when receiving such signals which are superior when compared with prior art systems. The frame synchronization algorithm in accordance with the present invention provides all of the properties shown in Table 1 in contrary to known frame synchronization procedures. Table 1 shows a comparison between the system in accordance with the present invention using an AM sequence as reference symbol and prior art systems (single carrier and MCM Eureka 147).

Table 1

	single carrier (e.g. QPSK like WS)	MCM Eureka 147	MCM with AM sequence
carrier offset allowed	no	yes	yes
constant power achieved at Rx input	yes	no	yes
coarse frequency offset estimation possible	no	no	yes
coarse channel estimation possible (cluster estimation)	yes	no	yes

As can be seen from Table 1 different synchronization tasks and parameters can be derived using the frame synchronization with an AM sequence in accordance with the present invention. The frame synchronization procedure MCM Eureka 147 corresponds to the procedure described in US-A-5,191,576.

CLAIMS

1. A method for generating a signal having a frame structure, each frame of said frame structure comprising at least one useful symbol (12), a guard interval (14) associated to said at least one useful symbol (12) and a reference symbol (16), said method comprising the step of

   performing an amplitude modulation of a bit sequence such that the envelope of the amplitude modulated bit sequence defines a reference pattern of said reference symbol (16).

2. The method according to claim 1, wherein said signal is an orthogonal frequency division multiplexed signal.

3. The method according to claim 1 or 2, wherein said amplitude modulation is performed such that a mean amplitude of said reference symbol (16) substantially corresponds to a mean amplitude of the remaining signal.

4. A method for generating a multi-carrier modulated signal having a frame structure, each frame of said frame structure comprising at least one useful symbol (12), a guard interval (14) associated to said at least one useful symbol (12) and a reference symbol (16), said method comprising the steps of:

   providing a bitstream (104);

   mapping bits of said bitstream (104) to carriers in order to provide a sequence of spectra (108);

   performing an inverse Fourier transform (110) in order to provide multi-carrier modulated symbols (112);

   associating (114) a guard interval to each multi-carrier modulated symbol;

   generating said reference symbol (16) by performing an

amplitude modulation of a bit sequence such that the envelope of the amplitude modulated bit sequence defines a reference pattern of said reference symbol; and

associating (116) said reference symbol (16) to a predetermined number of multi-carrier modulated symbols and associated guard intervals in order to define said frame.

5. The method according to claim 4, wherein said multi-carrier modulated signal is an orthogonal frequency division multiplex signal.

6. The method according to claim 4 or 5, wherein said amplitude modulation is performed such that a mean amplitude of said reference symbol (16) substantially corresponds to a mean amplitude of the remaining multi-carrier modulated signal.

7. The method according to one of claims 1 to 6, wherein said bit sequence is a pseudo random bit sequence having good autocorrelation characteristics.

8. The method according to one of claims 1 to 7, wherein a number of useful symbols (12) in each frame is defined depending on channel properties of a channel (122) through which the signal or the multi-carrier modulated signal is transmitted.

9. A method for frame synchronization of a signal having a frame structure, each frame of said frame structure comprising at least one useful symbol (12), a guard interval (14) associated with said at least one useful symbol (12) and a reference symbol (16), said method comprising the steps of:

receiving said signal;

down-converting said received signal;

performing (164) an amplitude-demodulation of said down-converted signal in order to generate an envelope;

correlating (166) said envelope with a predetermined reference pattern in order to detect a signal reference pattern of said reference symbol (16) in said signal; and

performing said frame synchronization based on the detection of said signal reference pattern.

10. The method according to claim 9, further comprising the step of performing a fast automatic gain control (162) of said received down-converted signal prior to the step of performing said amplitude-demodulation (164).

11. The method according to claim 9 or 10, wherein the step of performing (164) said amplitude-demodulation comprises the step of calculating an amplitude of said signal using the $alpha_{max+}$ $beta_{min-}$ method.

12. The method according to claim 9 or 10, further comprising the steps of sampling respective amplitudes of said received down-converted signal and comparing said sampled amplitudes with a predetermined threshold in order to generate a bit sequence in order to perform said amplitude demodulation.

13. The method according to claim 12, wherein the step of sampling respective amplitudes of said received down-converted signal further comprises the step of performing an over-sampling of said received down-converted signal.

14. The method according to any one of claims 9 to 13, further comprising the step of applying a result of the frame synchronization for a frame in said signal to at least one subsequent frame in said signal.

15. A method for frame synchronization of a multi-carrier

modulated signal having frame structure, each frame of said frame structure comprising at least one useful symbol (12), a guard interval (14) associated to said at least one useful symbol (12) and a reference symbol (16), said method comprising the steps of:

receiving said multi-carrier modulated signal;

down-converting said received multi-carrier modulated signal;

performing (164) an amplitude-demodulation of said down-converted multi-carrier modulated signal in order to generate an envelope;

correlating (166) said envelope with a predetermined reference pattern in order to detect a signal reference pattern of said reference symbol in said multi-carrier modulated signal;

performing said frame synchronization based on the detection of said signal reference pattern;

extracting (136/138) said reference symbol (16) and said at least one guard interval (14) from said down-converted received multi-carrier modulated signal based on said frame synchronization;

performing (140) a Fourier transform in order to provide a sequence of spectra from said at least one useful symbol;

de-mapping (142) said sequence of spectra in order to provide a bitstream.

16. The method according to claim 15, further comprising the step of performing (162) a fast automatic gain control of said received down-converted multi-carrier modulated signal prior to the step of performing said amplitude-demodulation.

17. The method according to claim 15 or 16, wherein the step of performing (164) said amplitude-demodulation comprises the step of calculating an amplitude of said multi-carrier modulated signal using the $alpha_{max+}$ $beta_{min-}$ method.

18. The method according to claim 15 or 16, further comprising the steps of sampling respective amplitudes of said received down-converted multi-carrier modulated signal and comparing said sampled amplitudes with a predetermined threshold in order to generate a bit sequence in order to perform said amplitude demodulation.

19. The method according to claim 18, wherein the step of sampling respective amplitudes of said received down-converted multi-carrier modulated signal further comprises the step of performing an over-sampling of said received down-converted multi-carrier modulated signal.

20. The method according to one of claims 15 to 19, further comprising the step of applying a result of the frame synchronization for a frame in said signal to at least one subsequent frame in said multi-carrier modulated signal.

21. The method according to one of claims 9 to 20, further comprising the step of detecting a location of said signal reference pattern based on an occurrence of a maximum of a correlation signal when correlating said envelope with said predetermined reference pattern.

22. The method according to claim 21, further comprising the steps of:

weighting a plurality of maxima of said correlation signal such that a maximum occurring first is weighted stronger than any subsequently occurring maximum; and

detecting said location of said signal reference pattern based on the greatest one of said weighted maxima.

23. The method according to claim 22, further comprising the step of:

disabling the step of performing said frame synchronization for a predetermined period of time after having switched-on a receiver (130) performing said method for frame synchronization.

24. An apparatus for generating a signal having a frame structure, each frame of said frame structure comprising at least one useful symbol (12), a guard interval (14) associated to said at least one useful symbol (12) and a reference symbol (14), said apparatus comprising:

an amplitude modulator for performing an amplitude modulation of a bit sequence such that the envelope of the amplitude modulated bit sequence defines a reference pattern of said reference symbol (16).

25. The apparatus according to claim 24, wherein said signal is an orthogonal frequency division multiplexed signal.

26. The apparatus according to claim 24 or 25, wherein a mean amplitude of said reference symbol (16) substantially corresponds to a mean amplitude of the remaining signal.

27. An apparatus for generating a multi-carrier modulated signal having a frame structure, each frame of said frame structure comprising at least one useful symbol (12), a guard interval (14) associated to said at least one useful symbol (12) and a reference symbol (16), said apparatus comprising:

means (102) for providing a bitstream (104);

means (106) for mapping bits of said bitstream (104) to carriers in order to provide a sequence of spectra (108);

means (110) for performing an inverse Fourier transform in order to provide multi-carrier modulated symbols (112);

means (114) for associating a guard interval to each multi-carrier modulated symbol;

means for generating said reference symbol (16) comprising an amplitude modulator for performing an amplitude modulation of a bit sequence such that the envelope of the amplitude modulated bit sequence defines a reference pattern of said reference symbol (16); and

means (116) for associating said reference symbol (16) to a predetermined number of multi-carrier modulated symbols (12) and associated guard intervals (14) in order to define said frame.

28. The apparatus according to claim 27, wherein said multi-carrier modulated signal is an orthogonal frequency division multiplex signal.

29. The apparatus according to claim 26 or 27, wherein said means for generating said reference symbol (16) performs the amplitude modulation such that a mean amplitude of said reference symbol (16) substantially corresponds to a mean amplitude of the remaining multi-carrier modulated signal.

30. The apparatus according to one of claims 24 to 29, wherein said means for generating said reference symbol (16) generates a pseudo random bit sequence having good autocorrelation characteristics as said bit sequence.

31. The apparatus according to one of claims 24 to 30, comprising means for determining a number of useful symbols (12) in each frame depending on channel properties of a channel (122) through which the signal or the multi-carrier modulated signal is transmitted.

32. An apparatus for frame synchronization of a signal having a

frame structure, each frame of said frame structure comprising at least one useful symbol (12), a guard interval (14) associated to said at least one useful symbol (12) and a reference symbol (16), said apparatus comprising:

receiving means (150) for receiving said signal;

a down-converter for down-converting said received signal;

an amplitude-demodulator (164) for performing an amplitude demodulation of said down-converted signal in order to generate an envelope;

a correlator (166) for correlating said envelope with a predetermined reference pattern in order to detect a signal reference pattern of said reference symbol (16) in said signal; and

means for performing said frame synchronization based on the detection of said signal reference pattern.

33. The apparatus according to claim 32, further comprising means (162) for performing a fast automatic gain control of said received down-converted signal preceding said amplitude-demodulator (164).

34. The apparatus according to claim 32 or 33, wherein said amplitude-demodulator (164) comprises means for calculating an amplitude of said signal using the $alpha_{max+}$ $beta_{min}$-method.

35. The apparatus according to claim 32 or 33, further comprising means for sampling respective amplitudes of said received down-converted signal, wherein said amplitude-demodulator (164) comprises means for comparing said sampled amplitudes with a predetermined threshold in order to generate a bit sequence.

36. The apparatus according to claim 35, wherein said means for sampling comprises means for over-sampling said received down-converted signal.

37. The apparatus according to one of claims 32 to 36, further comprising means for applying a result of the frame synchronization for a frame in said signal to at least one subsequent frame in said signal.

38. An apparatus for frame synchronization of a multi-carrier modulated signal having a frame structure, each frame of said frame structure comprising at least one useful symbol (12), a guard interval (14) associated to said at least one useful symbol (12) and a reference symbol (16), said apparatus comprising:

a receiver (150) for receiving said multi-carrier modulated signal;

a down-converter for down-converting said received multi-carrier modulated signal;

an amplitude-demodulator (164) for performing an amplitude-demodulation of said down-converted multi-carrier modulated signal in order to generate an envelope;

a correlator (166) for correlating said envelope with a predetermined reference pattern in order to detect a signal reference pattern of said reference symbol (16) in said multi-carrier modulated signal;

means for performing said frame synchronization based on the detection of said signal reference pattern;

means (136/138) for extracting said reference symbol (16) and said at least one guard interval (14) from said down-converted received multi-carrier modulated signal based on said frame synchronization in order to generate said at least one useful symbol;

means (140) for performing a Fourier transform in order to provide a sequence of spectra from said at least one useful symbol; and

means (142) for de-mapping said sequence of spectra in order to provide a bitstream.

39. The apparatus according to claim 38, further comprising means (162) for performing a fast automatic gain control of said received down-converted multi-carrier modulated signal preceding said amplitude-demodulator (164).

40. The apparatus according to claim 38 or 39, wherein said amplitude-demodulator (164) comprises means for calculating an amplitude of said multi-carrier modulated signal using the alpha_{max+} beta_{min-} method.

41. The apparatus according to claim 38 or 39, further comprising means for sampling respective amplitudes of said received down-converted multi-carrier modulated signal, wherein said amplitude-demodulator (164) comprises means for comparing said sampled amplitudes with a predetermined threshold in order to generate a bit sequence.

42. The apparatus according to claim 41, wherein said means for sampling comprises means for over-sampling said received down-converted multi-carrier modulated signal.

43. The apparatus according to one of claims 38 to 42, further comprising means for applying a result of the frame synchronization for a frame in said multi-carrier modulated signal to at least one subsequent frame in said multi-carrier modulated signal.

44. The apparatus according to one of claims 32 to 43, further comprising means for detecting a location of said signal reference pattern based on an occurrence of a maximum of a correlation signal output of said correlator (166).

45. The apparatus according to claim 44, further comprising means for weighting a plurality of maxima of said correlation signal such that a maximum occurring first is weighted stronger than any subsequently occurring maximum; and

means for detecting said location of said signal reference pattern based on the greatest one of said weighted maxima.

46. The apparatus according to claim 45, further comprising means for disabling said means for performing said frame synchronization for a predetermined period of time after having switched-on a receiver (130) comprising said apparatus for frame synchronization.

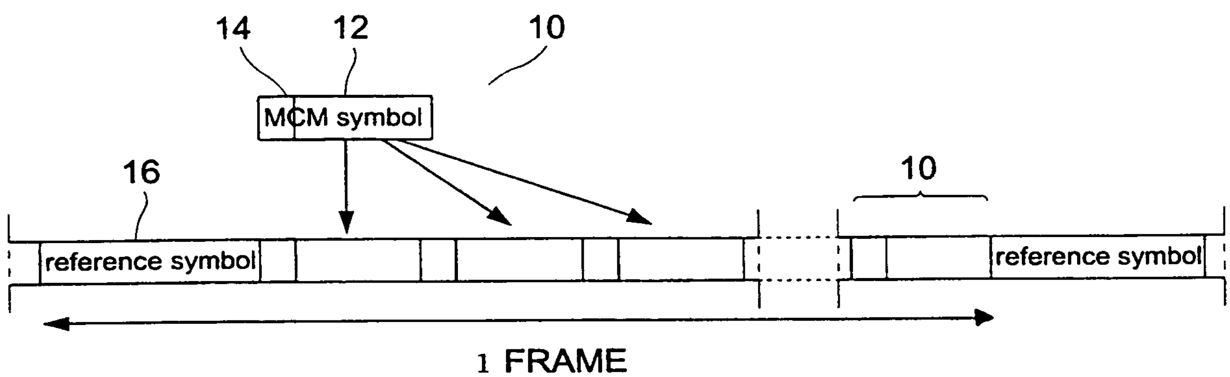

14
12
10
MCM symbol
16
10
reference symbol
reference symbol
1 FRAME

FIG.1

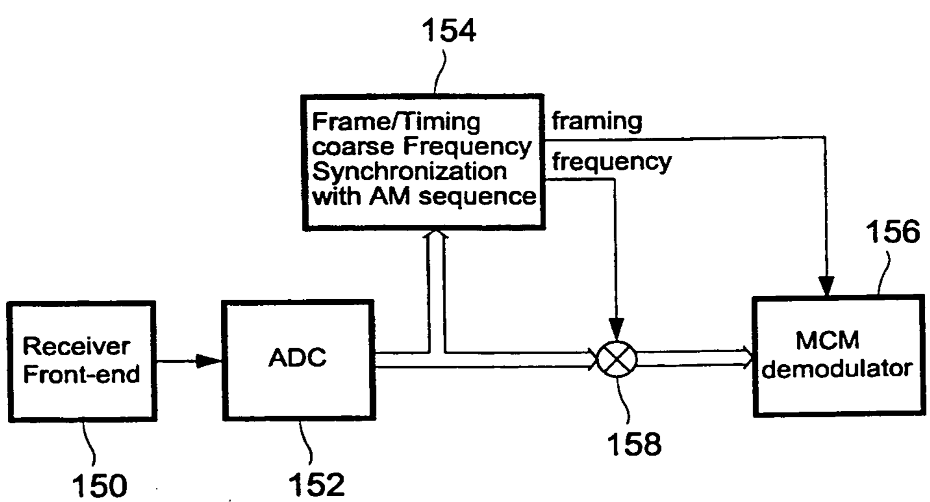

154
Frame/Timing coarse Frequency Synchronization with AM sequence
framing
frequency
156
Receiver Front-end
ADC
MCM demodulator
158
150
152

FIG.3

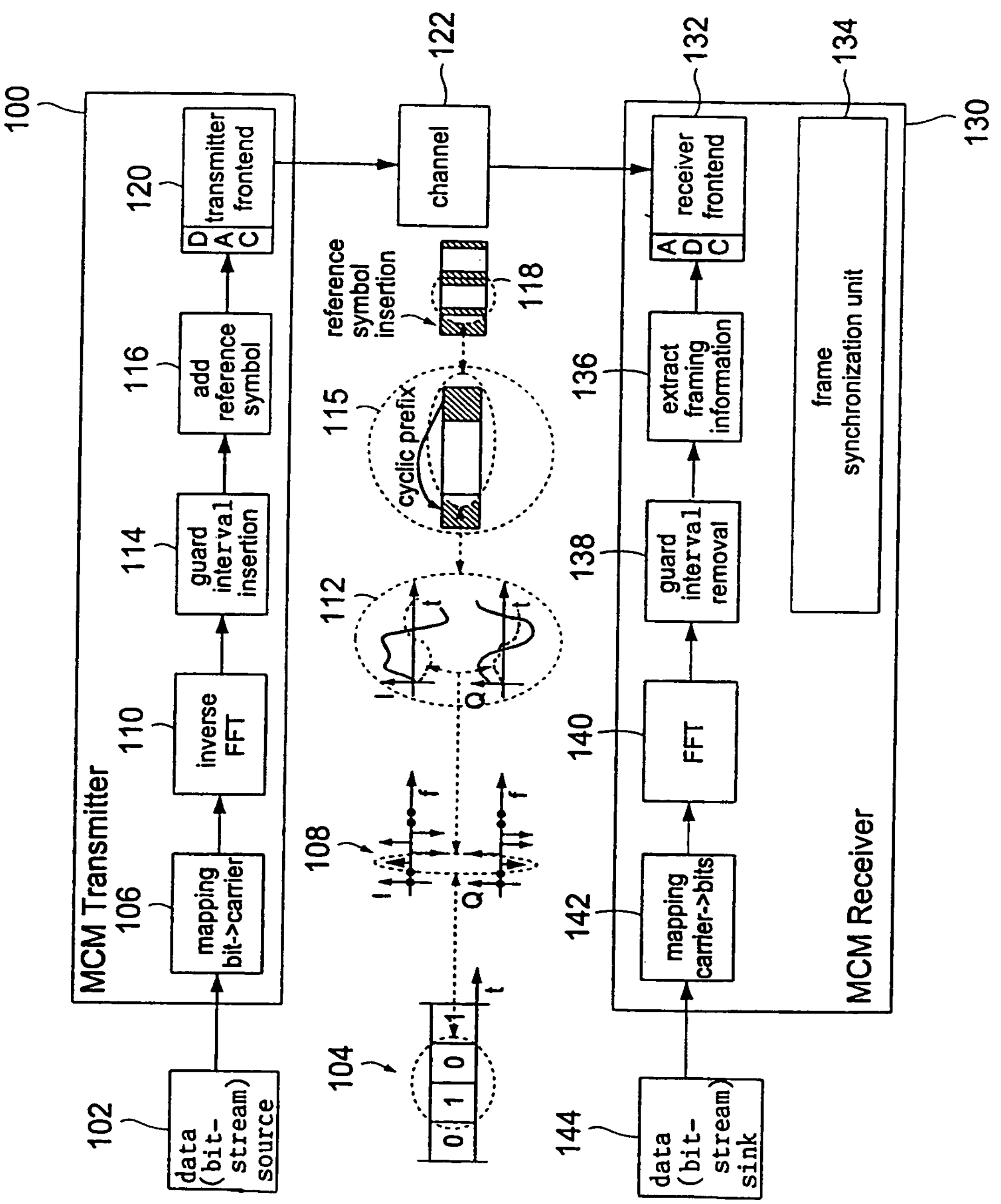

MCM Transmitter
data (bit-stream) source
mapping bit->carrier
inverse FFT
guard interval insertion
add reference symbol
D A C
transmitter frontend
channel
reference symbol insertion
cyclic prefix
MCM Receiver
receiver frontend
A D C
extract framing information
guard interval removal
FFT
mapping carrier->bits
data (bit-stream) sink
frame synchronization unit
100
102
104
106
108
110
112
114
115
116
118
120
122
130
132
134
136
138
140
142
144

FIG.2

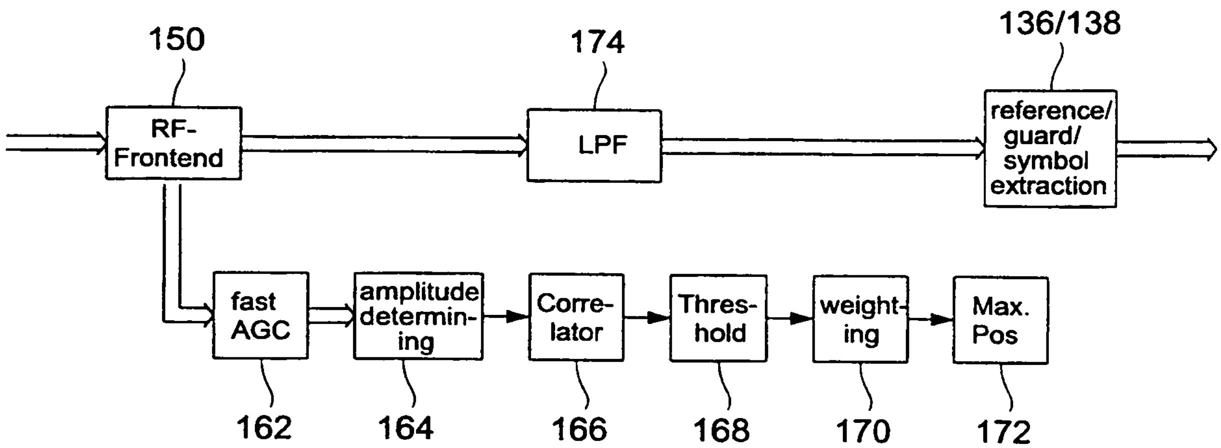

150
174
136/138
RF-Frontend
LPF
reference/ guard/ symbol extraction
fast AGC
amplitude determin-ing
Corre-lator
Thres-hold
weight-ing
Max. Pos
162
164
166
168
170
172

FIG.4

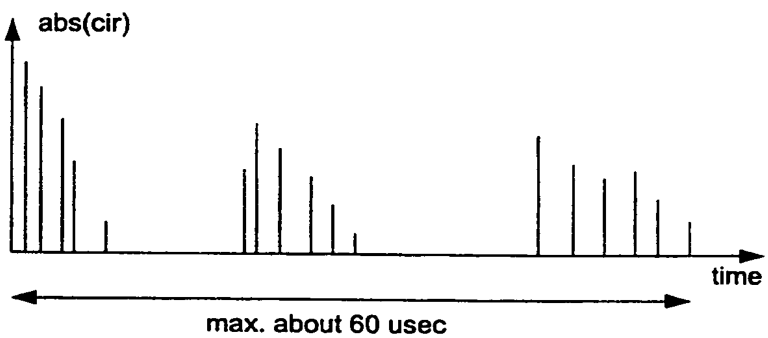

abs(cir)
time
max. about 60 usec

FIG.5

INTERNA NAL SEARCH REPORT

Intern. al Application No
PCT/EP 98/02169

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04L27/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 631 406 A (FRANCE TELECOM; TELEDIFFUSION DE FRANCE) 28 December 1994 see page 3, line 27 - line 28 ---	1-7,9, 15, 24-30, 32,38
A	WO 98 00946 A (LELAND STANFORD JUNIOR UNIVERSITY) 8 January 1998 see page 17, line 16 - line 22 see page 26, line 17 - page 27, line 2 see page 27, line 14 - line 24 see page 28, line 4 - line 16 --- -/--	1,4,9, 15,24, 27,32,38

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 January 1999	14/01/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Scriven, P

1

International Application No
PCT/EP 98/02169

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	MOOSE: "A technique for orthogonal frequency division multiplexing frequency offset correction" IEEE TRANSACTIONS ON COMMUNICATIONS., vol. 42, no. 10, October 1994, pages 2908-2914, XP002019915 NEW YORK, US cited in the application see page 2908, right-hand column, paragraph 5 see page 2911, right-hand column, paragraph 5 - page 2912, right-hand column, paragraph 2 ---	1,4,9, 15,24, 27,32,38
A	KELLER; HANZO: "Orthogonal frequency division muliplex synchronisation techniques for wireless local area networks" IEEE INTERNATIONAL SYMPOSIUM ON PERSONAL, INDOOR AND MOBILE RADIO COMMUNICATIONS, 15 October 1996, pages 963-967, XP002063294 New York, US see page 963, right-hand column, paragraph 3 ---	1,4,9, 15,24, 27,32,38
A	PALACHERLA: "DSP- P routine computes magnitude" EDN ELECTRICAL DESIGN NEWSW, vol. 34, no. 22, 26 October 1989, pages 225-226, XP000070840 NEWTON, MASSACHUSETTS, US see the whole document -----	11,12, 40,41

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 98/02169

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0631406 A	28-12-1994	FR 2707064 A	30-12-1994
WO 9800946 A	08-01-1998	US 5732113 A	24-03-1998

Form PCT/ISA/210 (patent family annex) (July 1992)

AK 09/673271

REVISED VERSION*

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04L 27/26	A1	(11) International Publication Number: WO 99/53665 (43) International Publication Date: 21 October 1999 (21.10.99)

(21) International Application Number: PCT/EP98/02169

(22) International Filing Date: 14 April 1998 (14.04.98)

(71) Applicant (for all designated States except US): FRAUNHNOFER-GESELLSCHAFT ZUR FÖRDERUNG DER ANGEWAND TEN FORSCHUNG E.V. [DE/DE]; Leonrodstrasse 54, D-80636 München (DE).

(72) Inventors; and
(75) Inventors/Applicants (for US only): EBERLEIN, Ernst [DE/DE]; Waldstrasse 28 b, D-91091 Großenseebach (DE). BADRI, Sabah [MA/DE]; Sebaldusstrasse 8, D-91058 Erlangen (DE). LIPP, Stefan [DE/DE]; Steinweg 9 a, D-91058 Erlangen (DE). BUCHHOLZ, Stephan [DE/DE]; Kerschlacher Strasse 8, D-81447 München (DE). HEUBERGER, Albert [DE/DE]; Hausäckerweg 18, D-91056 Erlangen (DE). GERHÄUSER, Heinz [DE/DE]; Saugendorf 17, D-91344 Waischenfeld (DE).

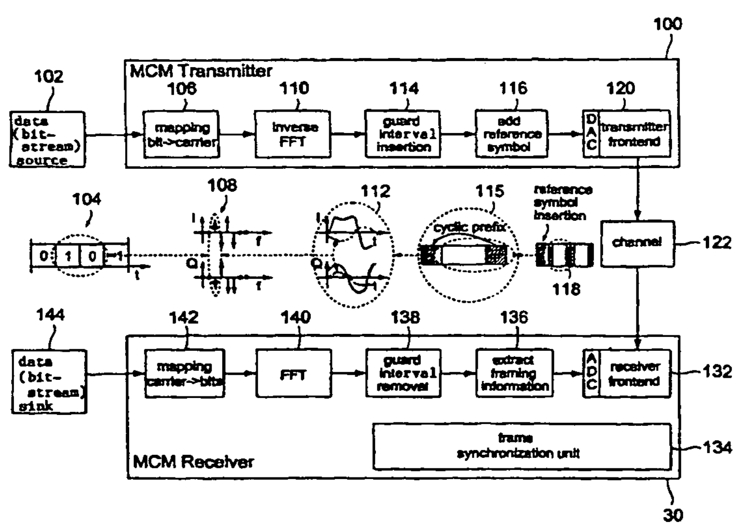
(74) Agent: SCHOPPE, Fritz; Schoppe & Zimmermann, Postfach 71 08 67, D-81458 München (DE).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With a revised version of the international search report.

(88) Date of publication of the revised version of the international search report: 16 November 2000 (16.11.00)

(54) Title: FRAME STRUCTURE AND FRAME SYNCHRONIZATION FOR MULTICARRIER SYSTEMS



(57) Abstract

A method for generating a signal having a frame structure, each frame of the frame structure comprising at least one useful symbol (12), a guard interval (14) associated to the at least one useful symbol (12) and a reference symbol (16), comprises the step of performing an amplitude modulation of a bit sequence such that the envelope of the amplitude modulated bit sequence defines a reference pattern of the reference symbol (16). A method for frame synchronization of a signal having a frame structure comprises the steps of receiving the signal, down-converting the received signal, performing (164) an amplitude-demodulation of the down-converted signal in order to generate an envelope, correlating (166) the envelope with a predetermined reference pattern in order to detect a signal reference pattern of the reference symbol (16) in the signal, and performing the frame synchronization based on the detection of the signal reference pattern.

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Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	**ES**	Spain	**LS**	Lesotho	**SI**	Slovenia
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EE	Estonia	**LR**	Liberia	**SG**	Singapore		

REVISED VERSION

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 98/02169

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04L27/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	WO 98 00946 A (LELAND STANFORD JUNIOR UNIVERSITY) 8 January 1998 see page 17, line 16 - line 22 see page 26, line 17 - page 27, line 2 see page 27, line 14 - line 24 see page 28, line 4 - line 16 --- -/--	1,4,9, 15,24, 27,32,38

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 January 1999	14/01/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Scriven, P

1

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	MOOSE: "A technique for orthogonal frequency division multiplexing frequency offset correction" IEEE TRANSACTIONS ON COMMUNICATIONS., vol. 42, no. 10, October 1994, pages 2908-2914, XP002019915 NEW YORK, US cited in the application see page 2908, right-hand column, paragraph 5 see page 2911, right-hand column, paragraph 5 - page 2912, right-hand column, paragraph 2 ---	1,4,9, 15,24, 27,32,38
A	KELLER; HANZO: "Orthogonal frequency division muliplex synchronisation techniques for wireless local area networks" IEEE INTERNATIONAL SYMPOSIUM ON PERSONAL, INDOOR AND MOBILE RADIO COMMUNICATIONS, 15 October 1996, pages 963-967, XP002063294 New York, US see page 963, right-hand column, paragraph 3 ---	1,4,9, 15,24, 27,32,38
A	PALACHERLA: "DSP- P routine computes magnitude" EDN ELECTRICAL DESIGN NEWSW, vol. 34, no. 22, 26 October 1989, pages 225-226, XP000070840 NEWTON, MASSACHUSETTS, US see the whole document -----	11,12, 40,41

INTERNATIONAL SEARCH REPORT

...ormation on patent family members

Intern· al Application No
PCT/EP 98/02169

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0631406 A	28-12-1994	FR 2707064 A	30-12-1994
WO 9800946 A	08-01-1998	US 5732113 A	24-03-1998

PCT

REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

For receiving Office use only

International Application No.

International Filing Date

Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference *(if desired) (12 characters maximum)* FH980402PCT

Box No. I TITLE OF INVENTION

METHOD AND APPARATUS FOR GENERATING A SIGNAL HAVING A FRAME STRUCTURE AND METHOD AND APPARATUS FOR FRAME SYNCHRONIZATION

Box No. II APPLICANT

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

Fraunhofer-Gesellschaft zur Förderung
der angewandten Forschung e. V.
Leonrodstraße 54
D-80636 München
DE

☐ This person is also inventor.

Telephone No.

Facsimile No.

Teleprinter No.

State *(i.e. country)* of nationality: DE

State *(i.e. country)* of residence: DE

This person is applicant for the purposes of: ☐ all designated States [XX] all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

EBERLEIN, Ernst
Waldstraße 28 b
D-91091 Großenseebach
DE

This person is:

☐ applicant only

[XX] applicant and inventor

☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality: DE

State *(i.e. country)* of residence: DE

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America [X] the United States of America only ☐ the States indicated in the Supplemental Box

[XX] Further applicants and/or (further) inventors are indicated on a continuation sheet.

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: [X] agent ☐ common representative

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

SCHOPPE, Fritz
Schoppe & Zimmermann
Postfach 71 08 67
D-81458 München
DE

Telephone No. 0 89/7 90 445-0

Facsimile No. 0 89/7 90 22 15

Teleprinter No. —

☐ Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Continuation of Box No. III **FURTHER APPLICANTS AND/OR (FURTHER) INVENTORS**

If none of the following sub-boxes is used, this sheet is not to be included in the request.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

BADRI, Sabah
Sebaldusstraße 8
D-91058 Erlangen
DE

This person is:
- [ ] applicant only
- [X] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality: MA

State *(i.e. country)* of residence: DE

This person is applicant for the purposes of:
- [ ] all designated States
- [ ] all designated States except the United States of America
- [X] the United States of America only
- [ ] the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

LIPP, Stefan
Steinweg 9 a
D-91058 Erlangen
DE

This person is:
- [ ] applicant only
- [X] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality: DE

State *(i.e. country)* of residence: DE

This person is applicant for the purposes of:
- [ ] all designated States
- [ ] all designated States except the United States of America
- [X] the United States of America only
- [ ] the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

BUCHHOLZ, STEPHAN
Spinnereistraße 20
D-91052 Erlangen
DE

This person is:
- [ ] applicant only
- [X] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality: DE

State *(i.e. country)* of residence: DE

This person is applicant for the purposes of:
- [ ] all designated States
- [ ] all designated States except the United States of America
- [X] the United States of America only
- [ ] the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

HEUBERGER, Albert
Hausäckerweg 18
D-91056 Erlangen
DE

This person is:
- [ ] applicant only
- [X] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality: DE

State *(i.e. country)* of residence: DE

This person is applicant for the purposes of:
- [ ] all designated States
- [ ] all designated States except the United States of America
- [X] the United States of America only
- [ ] the States indicated in the Supplemental Box

- [X] Further applicants and/or (further) inventors are indicated on another continuation sheet.

Continuation of Box No. III FURTHER APPLICANTS AND/OR (FURTHER) INVENTORS

If none of the following sub-boxes is used, this sheet is not to be included in the request.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

GERHÄUSER, Heinz
Saugendorf 17
D-91344 Waischenfeld
DE

This person is:
- ☐ applicant only
- ☒ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality: DE

State *(i.e. country)* of residence: DE

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

This person is:
- ☐ applicant only
- ☐ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality:

State *(i.e. country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

This person is:
- ☐ applicant only
- ☐ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality:

State *(i.e. country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

This person is:
- ☐ applicant only
- ☐ applicant and inventor
- ☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality:

State *(i.e. country)* of residence:

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

☐ Further applicants and/or (further) inventors are indicated on another continuation sheet.

Box No.V DESIGNATION OF STATES

The following designations are hereby made under Rule 4.9(a) *(mark the applicable check-boxes; at least one must be marked)*:

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☒ AP **ARIPO Patent:** KE Kenya, LS Lesotho, MW Malawi, SD Sudan, SZ Swaziland, UG Uganda, and any other State which is a Contracting State of the Harare Protocol and of the PCT

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☒ OA **OAPI Patent:** BF Burkina Faso, BJ Benin, CF Central African Republic, CG Congo, CI Côte d'Ivoire, CM Cameroon, GA Gabon, GN Guinea, ML Mali, MR Mauritania, NE Niger, SN Senegal, TD Chad, TG Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT *(if other kind of protection or treatment desired, specify on dotted line)* ....

National Patent *(if other kind of protection or treatment desired, specify on dotted line)*:

☒ AL Albania
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☒ AT Austria ....
☒ AU Australia ....
☒ AZ Azerbaijan
☒ BB Barbados
☒ BG Bulgaria ....
☒ BR Brazil ....
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☒ CH and LI Switzerland and Liechtenstein
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☒ DE Germany ....
☒ DK Denmark ....
☒ EE Estonia ....
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☒ KP Democratic People's Republic of Korea ....
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☒ KR Republic of Korea ....
☒ KZ Kazakstan ....
☒ LK Sri Lanka
☒ LR Liberia
☒ LS Lesotho ....
☒ LT Lithuania
☒ LU Luxembourg ....
☒ LV Latvia
☒ MD Republic of Moldova ....
☒ MG Madagascar ....
☒ MK The former Yugoslav Republic of Macedonia
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☒ MN Mongolia
☒ MW Malawi ....
☒ MX Mexico ....
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☒ NZ New Zealand ....
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☒ RO Romania
☒ RU Russian Federation ....
☒ SD Sudan
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☒ SG Singapore
☒ SI Slovenia ....
☒ SK Slovakia ....
☒ TJ Tajikistan ....
☒ TM Turkmenistan ....
☒ TR Turkey ....
☒ TT Trinidad and Tobago ....
☒ UA Ukraine
☒ UG Uganda ....
☒ US United States of America ....
....
☒ UZ Uzbekistan ....
☒ VN Viet Nam ....

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☒ Israel (IL).......... ☒ Jugoslavia (YU)
☒ Saint Lucia (LC).. ☒ Zimbabwe (ZW)

In addition to the designations made above, the applicant also makes under Rule 4.9(b) all designations which would be permitted under the PCT except the designation(s) of ____________.
The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. *(Confirmation of a designation consists of the filing of a notice specifying that designation and the payment of the designation and confirmation fees. Confirmation must reach the receiving Office within the 15-month time limit.)*

Box No. VI PRIORITY CLAIM		Further priority claims are indicated in the Supplemental Box ☐	
The priority of the following earlier application(s) is hereby claimed:			
Country *(in which, or for which, the application was filed)*	Filing Date *(day/month/year)*	Application No.	Office of filing *(only for regional or international application)*
item (1)			
item (2)			
item (3)			

Mark the following check-box if the certified copy of the earlier application is to be issued by the Office which for the purposes of the present international application is the receiving Office (a fee may be required):

☐ The receiving Office is hereby requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) identified above as item(s) : ____________

Box No. VII INTERNATIONAL SEARCHING AUTHORITY

Choice of International Searching Authority (ISA) *(If two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used):* ISA / ____________

Earlier search *Fill in where a search (international, international-type or other) by the International Searching Authority has already been carried out or requested and the Authority is now requested to base the international search, to the extent possible, on the results of that earlier search. Identify such search or request either by reference to the relevant application (or the translation thereof) or by reference to the search request:*

Country (or regional Office): Date *(day/month/year)*: Number:

Box No. VIII CHECK LIST

This international application contains the following number of sheets:

1. request	:	5	sheets
2. description	:	25	sheets
3. claims	:	11	sheets
4. abstract	:	1	sheets
5. drawings	:	3	sheets
Total	:	45	sheets

This international application is accompanied by the item(s) marked below:

1. ☐ separate signed power of attorney
2. ☒ copy of general power of attorney
3. ☐ statement explaining lack of signature
4. ☐ priority document(s) *identified in Box No. VI as item(s):*
5. ☒ fee calculation sheet
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Munich, April 14, 1998 SCHOPPE, Fritz

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Fritz Schoppe, Dipl.-Ing.
Tankred Zimmermann, Dipl.-Ing.

Telefon/Telephone 089/790445-0
Telefax/Facsimile 089/790 22 15
Telefax/Facsimile 089/74996977

e-mail 101345, 3117 CompuServe

Schoppe & Zimmermann · Postfach 710867 · 81458 München

Fraunhofer-Gesellschaft
zur Förderung der
angewandten Forschung e. V.
Leonrodstraße 54
80636 München

METHOD AND APPARATUS FOR GENERATING A SIGNAL HAVING A FRAME STRUCTURE AND METHOD AND APPARATUS FOR FRAME SYNCHRONIZATION

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METHOD AND APPARATUS FOR GENERATING A SIGNAL HAVING A FRAME STRUCTURE AND METHOD AND APPARATUS FOR FRAME SYNCHRONIZATION

FIELD OF THE INVENTION

The present invention relates to methods and apparatus for generating a signal having a frame structure, wherein each frame of the frame structure is composed of useful symbols, a guard interval associated to each useful symbol and one reference symbol. In addition, the present invention relates to methods and apparatus for frame synchronization of signals having the above structure.

The present invention is particularly useful in a MCM transmission system (MCM = Multi-carrier modulation) using an orthogonal frequency division multiplexing (OFDM) for digital broadcasting.

BACKGROUND OF THE INVENTION

In a MCM (OFDM) transmission system the binary information is represented in the form of a complex spectrum, i.e. a distinct number of complex subcarrier symbols in the frequency domain. In the modulator a bitstream is represented by a sequence of spectra. Using an inverse Fourier-transform (IFFT) a MCM time domain signal is produced from this sequence of spectra.

In case of a transmission of this described MCM signal via a multipath channel with memory, intersymbol interference (ISI) occurs due to multipath dispersion. To avoid ISI a guard interval of fixed length is added between adjacent MCM symbols in time. The guard interval is chosen as cyclic prefix. This means that the last part of a time domain MCM symbol is placed in front of the symbol to get a periodic extension. If the fixed length of the chosen guard interval is greater than the maximum multipath delay, ISI will not occur.

In the receiver the information which is in the frequency and time domain (MCM) has to be recovered from the MCM time domain signal. This is performed in two steps. Firstly, optimally locating the FFT window, thus eliminating the guard interval in front of each MCM time domain symbol. Secondly, performing a Fourier Transform of the sequence of useful time samples thus obtained.

As a result a sequence of spectral symbols is thus recovered. Each of the symbols contains a distinct number of information carrying subcarrier symbols. Out of these, the information bits are recovered using the inverse process of the modulator.

Performing the above described method, the following problem occurs in the receiver. The exact position of the guard interval and hence the position of the original useful parts of the time domain MCM symbols is generally unknown. Extraction of the guard interval and the subsequent FFT-transform of the resulting useful part of the time signal is not possible without additional information. To provide this additional information, a known (single carrier) sequence in the form of a (time domain) reference symbol is inserted into the time signal. With the knowledge about the positions of the reference symbols in the received signal, the exact positions of the guard intervals and thus the interesting information carrying time samples are known.

The periodical insertion of the reference symbol results in a frame structure of the MCM signal. This frame structure of a MCM signal is shown in Figure 1. One frame of the MCM signal is composed of a plurality of MCM symbols 10. Each MCM symbol 10 is formed by an useful symbol 12 and a guard interval 14 associated therewith. As shown in Figure 1, each frame comprises one reference symbol 16.

A functioning synchronization in the receiver, i.e. frame, frequency, phase, guard interval synchronization is necessary for the subsequent MCM demodulation. Consequently, the first

and most important task of the base band processing in the receiver is to find and synchronize to the reference symbol.

DESCRIPTION OF THE PRIOR ART

Most prior art methods for frame synchronization have been developed for single carrier transmission over the AWGN channel (AWGN = Additive White Gaussian Noise). These prior art methods based on correlation are, without major changes, not applicable for transmission over multipath fading channels with large frequency offsets or MCM transmission systems that use, for example, an orthogonal frequency division multiplexing.

For MCM transmission systems particular frame synchronization methods have been developed.

Warner, W.D., Leung C.: OFDM/FM Frame Synchronization for Mobile Radio Data Communication, IEEE Trans. On Vehicular Technology, vol. VT-42, August 1993, pp. 302 to 313, teaches the insertion of reference symbols in the form of tones in parallel with the data into the MCM symbol. The reference symbols occupy several carriers of the MCM signal. In the receiver, the synchronization carriers are extracted in the frequency domain, after a FFT transform (FFT = fast Fourier transform) using a correlation detector. In the presence of large frequency offsets, this algorithm becomes very complex because several correlators must be implemented in parallel.

A further prior art technique is to insert a periodic reference symbol into the modulated MCM signal. This reference symbol is a CAZAC sequence (CAZAC = Constant Amplitude Zero Auto-correlation). Such techniques are taught by: Classen, F., Meyr, H.: Synchronization algorithms for an OFDM system for mobile communication, in *Codierung für Codierung für Quelle, Kanal und Übertragung*: ITG-Fachbericht 130, pp. 105-114, München, October 1994, ITG, VDE-Verlag, Berlin Offenbach; Lambrette, U., Horstmannshoff, J., Meyr, H.: Techniques for Frame Synchronization on Unknown Frequency Selective Channels, *Proc.*

Vehic. Technology Conference, 1997; Schmidl, T.M., Cox, D.C.: Low-Overhead, Low-Complexity [Burst] Synchronization for OFDM Transmission, *Proc. IEEE Int. Conf. on Commun.*, 1996. In such systems, the receiver's processor looks for a periodic repetition. For these algorithms coarse frequency synchronization has to be achieved prior to or at least simultaneously with frame synchronization.

Van de Beek, J, Sandell, M., Isaksson, M, Börjesson, P.: Low-Complex Frame Synchronization in OFDM Systems, *Proc. of the ICUPC*, 1995, avoid the insertion of additional reference symbols or pilot carriers and use instead the periodicity in the MCM signal which is inherent in the guard interval and the associated cyclical extension. This method is suitable only for slowly varying fading channels and small frequency offsets.

US-A-5,191,576 relates to a method for the diffusion of digital data designed to be received notably by mobile receivers moving in an urban environment. In this method, the header of each frame of a broadcast signal having a frame structure has a first empty synchronization symbol and a second unmodulated wobbled signal forming a two-stage analog synchronization system. The recovery of the synchronization signal is achieved in an analog way, without prior extraction of a clock signal at the binary level.

The methods for frame synchronization available up to date require either prior achieved frequency synchronization or become very complex when the signal in the receiver is corrupted by a large frequency offset.

If there is a frequency offset in the receiver, as can easily be the case when a receiver is powered-on and the frequency synchronization loop is not yet locked, problems will occur. When performing a simple correlation there will only be noise at the output of the correlator , i.e. no maximum can be found if the frequency offset exceeds a certain bound. The size of the frequency offset depends on the length (time) of the correlation to be performed, i.e. the longer it takes, the

smaller the allowed frequency offset becomes. In general, frequency offset increases implementation complexity.

Frequency offsets occur after power-on or later due to frequency deviation of the oscillators used for down-conversion to baseband. Typical accuracies for the frequency of a free running local oscillator (LO) are at ±50 ppm of the carrier frequency. With a carrier frequency in S-band (e.g. 2.34 GHz) there will be a maximum LO frequency deviation of above 100 kHz (117.25 kHz). A deviation of this magnitude puts high demands on the above methods.

In the case of multipath impaired transmission channel, a correlation method yields several correlation maxima in addition to the distinct maximum for an AWGN channel. The best possible frame header position, i.e. the reference symbol, has to be selected to cope with this number of maxima. In multipath channels, frame synchronization methods with correlations can not be used without major changes. Moreover, it is not possible to use data demodulated from the MCM system, because the demodulation is based on the knowledge of the position of the guard interval and the useful part of the MCM symbol.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method and an apparatus for generating a signal having a frame structure that allow a frame synchronization after the signals have been transmitted even in the case of a carrier frequency offset or in the case of a transmission via a multipath fading channel.

It is a further object of the present invention to provide a method and an apparatus for frame synchronization of a signal having a frame structure even in the case of a carrier frequency offset.

In accordance with a first aspect, the present invention

provides a method for generating a signal having a frame structure, each frame of the frame structure comprising at least one useful symbol, a guard interval associated to the at least one useful symbol and a reference symbol, the method comprising the step of performing an amplitude modulation of a bit sequence such that the envelope of the amplitude modulated bit sequence defines a reference pattern of the reference symbol.

In accordance with a second aspect, the present invention provides a method for generating a multi-carrier modulated signal having a frame structure, each frame of the frame structure comprising at least one useful symbol, a guard interval associated to the at least one useful symbol and a reference symbol, the method comprising the steps of:

providing a bitstream;

mapping bits of the bitstream to carriers in order to provide a sequence of spectra;

performing an inverse Fourier transform in order to provide multi-carrier modulated symbols;

associating a guard interval to each multi-carrier modulated symbol;

generating the reference symbol by performing an amplitude modulation of a bit sequence such that the envelope of the amplitude modulated bit sequence defines a reference pattern of the reference symbol; and

associating the reference symbol to a predetermined number of multi-carrier modulated symbols and associated guard intervals in order to define the frame.

In accordance with a third aspect, the present invention provides a method for frame synchronization of a signal having a frame structure, each frame of the frame structure comprising

at least one useful symbol, a guard interval associated with the at least one useful symbol and a reference symbol, the method comprising the steps of:

receiving the signal;

down-converting the received signal;

performing an amplitude-demodulation of the down-converted signal in order to generate an envelope;

correlating the envelope with a predetermined reference pattern in order to detect a signal reference pattern of the reference symbol in the signal; and

performing the frame synchronization based on the detection of the signal reference pattern.

In accordance with a fourth aspect, the present invention provides a method for frame synchronization of a multi-carrier modulated signal having frame structure, each frame of the frame structure comprising at least one useful symbol, a guard interval associated to the at least one useful symbol and a reference symbol, the method comprising the steps of:

receiving the multi-carrier modulated signal;

down-converting the received multi-carrier modulated signal;

performing an amplitude-demodulation of the down-converted multi-carrier modulated signal in order to generate an envelope;

correlating the envelope with a predetermined reference pattern in order to detect a signal reference pattern of the reference symbol in the multi-carrier modulated signal;

performing the frame synchronization based on the detection

of the signal reference pattern;

extracting the reference symbol and the at least one guard interval from the down-converted received multi-carrier modulated signal based on the frame synchronization;

performing a Fourier transform in order to provide a sequence of spectra from the at least one useful symbol;

de-mapping the sequence of spectra in order to provide a bitstream.

In accordance with a fifth aspect, the present invention provides an apparatus for generating a signal having a frame structure, each frame of the frame structure comprising at least one useful symbol, a guard interval associated to the at least one useful symbol and a reference symbol, the apparatus comprising an amplitude modulator for performing an amplitude modulation of a bit sequence such that the envelope of the amplitude modulated bit sequence defines a reference pattern of the reference symbol.

In accordance with a sixth aspect, the present invention provides an apparatus for generating a multi-carrier modulated signal having a frame structure, each frame of the frame structure comprising at least one useful symbol, a guard interval associated to the at least one useful symbol and a reference symbol, the apparatus comprising:

means for providing a bitstream;

means for mapping bits of the bitstream to carriers in order to provide a sequence of spectra;

means for performing an inverse Fourier transform in order to provide multi-carrier modulated symbols;

means for associating a guard interval to each multi-carrier modulated symbol;

means for generating the reference symbol by an amplitude modulator for performing an amplitude modulation of a bit sequence such that the envelope of the amplitude modulated bit sequence defines a reference pattern of the reference symbol; and

means for associating the reference symbol to a predetermined number of multi-carrier modulated symbols and associated guard intervals in order to define the frame.

In accordance with a seventh aspect, the present invention provides an apparatus for frame synchronization of a signal having a frame structure, each frame of the frame structure comprising at least one useful symbol, a guard interval associated to the at least one useful symbol and a reference symbol, the apparatus comprising:

receiving means for receiving the signal;

a down-converter for down-converting the received signal;

an amplitude-demodulator for performing an amplitude demodulation of the down-converted signal in order to generate an envelope;

a correlator for correlating the envelope with a predetermined reference pattern in order to detect a signal reference pattern of the reference symbol in the signal; and

means for performing the frame synchronization based on the detection of the signal reference pattern.

In accordance with a eighth aspect, the present invention provides an apparatus for frame synchronization of a multi-carrier modulated signal having a frame structure, each frame of the frame structure comprising at least one useful symbol, a guard interval associated to the at least one useful

symbol and a reference symbol, the apparatus comprising:

a receiver for receiving the multi-carrier modulated signal;

a down-converter for down-converting the received multi-carrier modulated signal;

an amplitude-demodulator for performing an amplitude-demodulation of the down-converted multi-carrier modulated signal in order to generate an envelope;

a correlator for correlating the envelope with a predetermined reference pattern in order to detect a signal reference pattern of the reference symbol in the multi-carrier modulated signal;

means for performing the frame synchronization based on the detection of the signal reference pattern;

means for extracting the reference symbol and the at least one guard interval from the down-converted received multi-carrier modulated signal based on the frame synchronization in order to generate the at least one useful symbol;

means for performing a Fourier transform in order to provide a sequence of spectra from the at least one useful symbol; and

means for de-mapping the sequence of spectra in order to provide a bitstream.

The present invention provides a novel structure of the reference symbol along with a method to determine the position of the reference symbol and thus the start of a frame in a signal having a frame structure as shown for example in Figure 1.

The invention relates to a method for finding frame headers independently of other synchronization information and thus for positioning the FFT windows correctly. This includes the extraction of a guard interval. The method is based on the detection of a known reference symbol of the frame header in the reception signal, e.g. in the digital complex baseband. The new frame synchronization will be performed as the first synchronization task.

Synchronization to the reference symbol, i.e. the frame header is the first step to initiate radio reception. The reference symbol is structured to accomplish this. The information contained in the reference symbol must therefore be independent of other synchronization parameters, e.g. frequency offset. For this reason, in accordance with the present invention, the form of the reference symbol selected is an amplitude modulated sequence (AM sequence) in the complex baseband. Thus, the information contained in the reference symbol is only that given in the amplitude and not that in the phase. Note that the phase information will be corrupted by a possible frequency offset. In preferred embodiments of the present invention, the AM information is constructed from a bit sequence with special features. The information sequence is selected in a way which makes it easy and secure to find it in the time domain. A bit sequence with good autocorrelation properties is chosen. Good autocorrelation properties means a distinct correlation maximum in a correlation signal which should be as white as possible.

A pseudo random bit sequence (PRBS) having good autocorrelation properties meets the above requirements.

Using the envelope of the signal to carry bit information offers additional flexibility. First it has to be decided which envelope values should correspond to the binary values of 0 and 1. The parameters are mean amplitude and modulation rate. Attention should be paid to selecting the mean amplitude of the reference symbol (performance) identically to the mean amplitude of the rest of the frame. This is due to the amplitude normalization (AGC; AGC = Automatic Gain Control)

performed in the receiver. It is also possible to select the mean amplitude of the reference symbol higher than the mean signal amplitude, but then care has to be taken that the time constant of the AGC (1/sensitivity) is selected high enough to secure that the strong (boosted) signal of the reference symbol does not influence the AGC control signal and thus attenuate the signal following the reference symbol.

Another degree of freedom can be characterized as modulation degree d. This parameter is responsible for the information density of the modulating signal mod(t) formed out of the binary sequence bin(t) as follows: mod(t) = bin(t/d). This modulation degree can be chosen as free parameter fixed by an integer or real relation to the sampling rate. It is appropriate to choose the modulation degree d as an integer value because of the discrete values of the binary sequence:

d = 1: mod(m)	= bin(m)	
d = 2: mod(m)	= bin(m/2)	for m even
	= bin_int(m/2)	for m odd
d = 3: mod(m)	= bin(m/3)	for m = 0, ±3, ±6, ±9, ...
	bin_int(m/3)	else

The signal values bin_int(m/d) are computed from the binary sequence bin(m) by ideal interpolation (between the discrete integer values m) with the factor of d. This is similar to an ideal sampling rate expansion (with sin(x)/x interpolation), but the sampling rate remains, only less bits of the binary sequence bin(m) correspond to the resulting interpolated sequence mod(m). This parameter m indicates the discrete time.

With increasing m the modulating signal mod(t) is expanded in time relative to the basic binary sequence, this results in a bandwidth compression of the resulting AM spectrum with regard to the basic binary sequence. A time expansion by a factor 2 results in a bandwidth compression by the same factor 2. In addition to the bandwidth compression, a further advantage of a higher modulation degree d is a reduced complexity of the search method in the receiver due to the fact that only each

d^{th} sample has a corresponding binary value. Choosing the factor d = 1 is not preferred since this would result in aliasing due to disregard of the sampling theorem. For this reason, in a preferred embodiment of the present invention d is chosen to be 2.

The choice of length and repetition rate of the reference symbol is, on the one hand, dominated by the channel properties, e.g. the channel's coherence time. On the other hand the choice depends on the receiver requirements concerning mean time for initial synchronization and mean time for resynchronization after synchronization loss due to a channel fade.

In the receiver, the first step after the down-conversion of the received signal is to perform an amplitude-demodulation of the down-converted signal in order to generate an envelope, i.e. in order to determine the amplitude of the signal. This envelope is correlated with a replica reference pattern in order to detect the signal reference pattern of the reference symbol in the signal. In the case of a AWGN channel, the result of this correlation will be a white noise signal with zero mean value and with a clearly visible (positive) maximum. In the case of a multipath channel, several maxima will occur in the correlation signal computed by this correlation. In the former case, the location of the reference symbol is determined based on the signal maximum, whereas in the latter case a weighting procedure is performed in order to find out the maximum corresponding to the location of the reference symbol.

Thus, the present invention shows how to find a reference symbol by a detection method which is simple. Furthermore, the present invention can be used for one-carrier or multi-carrier systems. The present invention is particularly useful in multi-carrier modulation systems using an orthogonal frequency division multiplexing, for example in the field of digital broadcasting. The synchronization methods according to the present invention are independent of other synchronization steps. Since the information needed for the synchronization is

contained in the envelope of the preamble, i.e. the reference symbol, the reference symbol is independent of possible frequency offsets. Thus, a derivation of the correct down sampling timing and the correct positioning of the FFT window can be achieved. The reference symbol of the present invention can be detected even if the frequency synchronization loop is not yet locked or even in the case of a carrier frequency offset. The frame synchronization method in accordance with the present invention is preferably performed prior to other and without knowledge of other synchronization efforts.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following, preferred embodiments of the present invention will be explained in detail on the basis of the drawings enclosed, in which:

Figure 1 shows a schematic view of a signal having a frame structure;

Figure 2 shows a block diagram of a MCM system to which the present invention can be applied;

Figure 3 shows a schematic block diagram of a frame and frequency synchronization system in a MCM receiver;

Figure 4 shows a schematic diagram of an apparatus for frame synchronization; and

Figure 5 shows a typical channel impulse response of a single frequency network in S-band.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Although the present invention is explained mainly referring to a MCM system, it is obvious that the present invention can be used in connection with different signal transmissions that are

based on different kinds of modulation.

Figure 2 shows a MCM system overview on the basis of which the present invention will be described in detail. At 100 a MCM transmitter is shown that substantially corresponds to a prior art MCM transmitter except for the kind of the reference symbol being added to each frame of a MCM signal. A description of such a MCM transmitter can be found, for example, in William Y. Zou, Yiyan Wu, "COFDM: AN OVERVIEW", IEEE Transactions on Broadcasting, vol. 41, No. 1, March 1995.

A data source 102 provides a serial bitstream 104 to the MCM transmitter. The incoming serial bitstream 104 is applied to a bit-carrier mapper 106 which produces a sequence of spectra 108 from the incoming serial bitstream 104. An inverse fast Fourier transform (FFT) 110 is performed on the sequence of spectra 108 in order to produce a MCM time domain signal 112. The MCM time domain signal forms the useful MCM symbol of the MCM time signal. To avoid intersymbol interference (ISI) caused by multipath distortion, a unit 114 is provided for inserting a guard interval of fixed length between adjacent MCM symbols in time. In accordance with a preferred embodiment of the present invention, the last part of the useful MCM symbol is used as the guard interval by placing same in front of the useful symbol. The resulting MCM symbol is shown at 115 in Figure 2 and corresponds to the MCM symbol 10 depicted in Figure 1.

In order to obtain the final frame structure shown in Figure 1, a unit 116 for adding a reference symbol for each predetermined number of MCM symbols is provided.

In accordance with the present invention, the reference symbol is an amplitude modulated bit sequence. Thus, an amplitude modulation of a bit sequence is performed such that the envelope of the amplitude modulated bit sequence defines a reference pattern of the reference symbol. This reference pattern defined by the envelope of the amplitude modulated bit sequence has to be detected when receiving the MCM signal at a MCM receiver. In a preferred embodiment of the present

invention, a pseudo random bit sequence having good auto-correlation properties is used as the bit sequence for the amplitude modulation.

The choice of length and repetition rate of the reference symbol depends on the properties of the channel through which the MCM signal is transmitted, e.g. the coherence time of the channel. In addition, the repetition rate and the length of the reference symbol, in other words the number of useful symbols in each frame, depends on the receiver requirements concerning mean time for initial synchronization and mean time for resynchronization after synchronization loss due to a channel fade.

The resulting MCM signal having the structure shown at 118 in Figure 2 is applied to the transmitter front end 120. Roughly speaking, at the transmitter front end 120, a digital/analog conversion and an up-converting of the MCM signal is performed. Thereafter, the MCM signal is transmitted through a channel 122.

Following, the mode of operation of a MCM receiver 130 is shortly described referring to Figure 2. The MCM signal is received at the receiver front end 132. In the receiver front end 132, the MCM signal is down-converted and, furthermore, a analog/digital conversion of the down-converted signal is performed. The down-converted MCM signal is provided to a frame synchronization unit 134. The frame synchronization unit 134 determines the location of the reference symbol in the MCM symbol. Based on the determination of the frame synchronization unit 134, a reference symbol extracting unit 136 extracts the framing information, i.e. the reference symbol, from the MCM symbol coming from the receiver front end 132. After the extraction of the reference symbol, the MCM signal is applied to a guard interval removal unit 138. The mode of operation of the frame synchronization unit 134 which represents the present invention will be described in detail referring to Figures 3 and 4 hereinafter.

The result of the signal processing performed hereherto in the MCM receiver is the useful MCM symbols.

The useful MCM symbols output from the guard interval removal unit 138 are provided to a fast Fourier transform unit 140 in order to provide a sequence of spectra from the useful symbols. Thereafter, the sequence of spectra is provided to a carrier-bit mapper 142 in which the serial bitstream is recovered. This serial bitstream is provided to a data sink 144.

Following, the mode of operation of the frame synchronization unit will be described in detail referring to Figures 3 and 4. Figure 3 represents a further high level diagram of an apparatus for frame synchronization of a MCM signal. In the receiver front end 150, the incoming MCM signal is down-converted. In Figure 3, an analog/digital converter 152 is shown separated from the receiver front end 150. The output signal of the analog/digital converter 152 is applied to a frame synchronization unit 154. This frame synchronization unit 154 performs the frame synchronization in accordance with the present invention which will be described in detail referring to Figure 4 hereinafter. Depending on the frame synchronization of the frame synchronization unit 154, a MCM demodulator 156 demodulates the MCM signal in order to provide a demodulated serial bitstream.

As shown in Figure 3, the described reference symbol in accordance with the present invention can also be used for a coarse frequency synchronization of the MCM signal. Namely, the frame synchronization unit 154 also serves as a coarse frequency synchronization unit for determining a coarse frequency offset of the carrier frequence caused, for example, by a difference of the frequencies between the local oscillator of the transmitter and the local oscillator of the receiver. The determined frequency offset is used in order to perform a coarse frequency correction at a point 158.

In Figure 4, a detailed schematic of the frame synchronization in accordance with the present application is depicted. A MCM

signal transmitted through the channel 122 is received at the receiver RF-front end 150. The down-converted MCM signal is sampled at the receiver front end 150 and is, in the preferred embodiment, provided to a fast running automatic gain control (time constant < MCM symbol duration) in order to eliminate fast channel fluctuations (channel coherence time ≈ MCM symbol duration). The fast AGC 162 is used in addition to the normally slow AGC in the signal path, in the case of transmission over a multipath channel with long channel impulse response and frequency selective fading. The fast AGC adjusts the average amplitude range of the signal to the known average amplitude of the reference symbol. The so processed symbol is provided to an amplitude determining unit 164.

The amplitude determining unit 164 can use the simple alpha_{max+} beta_{min-} method in order to calculate the amplitude of the signal. This method is described for example in Palachels A.: DSP-mP Routine Computes Magnitude, EDN, October 26, 1989; and Adams, W. T., and Bradley, J.: Magnitude Approximations for Microprocessor Implementation, IEEE Micro, Vol. 3, No. 5, October 1983.

The output signal of the amplitude determining unit 164 is applied to a correlator 166. In the correlator 166, a cross correlation between the amplitude signal output from the amplitude determining unit 164 and a known ideal amplitude information is computed. The known ideal amplitude information is stored in the correlator. For both, the amplitude and the known ideal amplitude information, their amplitudes are symmetrically to zero relative to their average amplitude.

In the ideal AWGN case, the result will be a white noise signal with zero mean value and with a clearly visible positive maximum. In this ideal AWGN case, the position of the single maximum is evaluated in a maximum position unit 172. On the basis of this evaluation, the reference symbol and the guard intervals are extracted from the MCM signal in a combined reference symbol/guard extraction unit 136/138. Although these units are shown as a combined unit 136/138 in Figure 4, it is

clear that separate units can be provided. The MCM signal is transmitted from the RF front end 150 to the reference symbol/guard extraction unit 136/138 via a low pass filter 174.

In the case of time spreading encountered in a multipath channel, several maxima corresponding to the number of clusters in the channel impulse response occur in the output signal of the correlator. A schematic view of three such clusters located in a time window of maximum about 60 microseconds is shown in Figure 5. Out of the several maxima caused by the time spreading encountered in a multipath channel, the best one has to be selected as the position of the frame header, i.e. the reference symbol. Therefore, a threshold unit 168 and a weighting unit 170 are provided between the correlator 166 and the maximum position unit 172. The threshold unit 168 is provided to remove maxima having an amplitude below a predetermined threshold. The weighting unit 164 is provided in order to perform a weighting procedure on the remaining maxima such that the maximum corresponding to the reference symbol can be determined. An examplary weighting procedure performed in the weighting unit 170 is as follows.

The first significant maximum is considered to be the best one. The output signal of the correlator is observed from the first detected maximum onwards for the maximum length of the channel impulse response and an amplitude weighting function is applied to the signal. Because the actual channel impulse response length is unknown, the following fact can be remembered. During system design, the length of the channel impulse response has to be investigated. In a MCM system, the guard interval shall be equal or longer than the maximum expected channel impulse response. For this reason, the part (interval with l_I samples, l_I corresponding to the maximum expected channel impulse response, i.e. the guard interval length) of the correlation output signal starting with the first maximum,

$$I(k_0) = \sum_{n=0}^{l_I-1} r(k_0+n) \qquad \text{(Eq.1)}$$

with k_0 being the position of the first maximum, will be

examined to find the best frame start position. The above signal part is weighted with the function

$$W(n) = 10^{-\frac{weight\_dB}{10}\frac{n}{l_I-1}} \qquad \text{(Eq.2)}$$

The position (n_{max}) of the maximum in the resulting signal interval

$$I_{weighted}(k_0) = \sum_{n=0}^{l_I-1}\left[r(k_0+n)W(n)\right] = \sum_{n=0}^{l_I-1}\left[r(k_0+n)\,10^{-\frac{weight\_dB}{10}\frac{n}{l_I-1}}\right] \qquad \text{(Eq.3)}$$

will be chosen as best frame start position.

r(k) designates the output signal of the correlator (166) at the time k. The signal is present with a clock frequency which is determined by the multiplication: oversampling factor * subcarrier symbol frequency. The parameter k designates the discrete time in sample clocks. This signal is windowed with information from the threshold unit 168. An interval having the length of l_I values is extracted from the signal r(k). The first value being written into the interval is the correlation start value at the time k_0, at which the output value $r(k_0)$ exceeds the threshold value of the threshold unit 168 for the first time. The interval with the windowed signal is designated by the term $I(k_0)$. The parameter n designates the relative time, i.e. position, of a value inside the interval.

Using the described weighting operation, the earlier correlation maxima are more likely to be chosen as right frame start position. A later coming maximum will only be chosen as frame start position, if the value of the maximum is significantly higher than the earlier one. This operation is applicable especially for MCM, because here it is better to detect the frame start positions some samples too early than some samples too late. Positioning the frame start some samples too early leads to positioning the FFT window a little bit into the guard interval, this contains information of the same MCM symbol and therefore leads to little effects. If the frame start position is detected some samples too late, then the FFT window includes some samples of the following guard interval.

This leads to a more visible degradation, because the following guard interval contains information of the following MCM symbol (ISI occurs).

It is important to know that the first visible correlation maximum after receiver power-on does not necessarily correspond to the first CIR cluster. It is possible that it is corresponding to a later cluster, see Figure 5. For this reason during power-on one should wait for a second frame start before starting demodulation.

It is clear that amplitude determining methods different from the described $alpha_{max+}$ $beta_{min-}$ method can be used. For simplification, it is possible to reduce the amplitude calculation to a detection as to whether the current amplitude is above or below the average amplitude. The output signal then consists of a -1/+1 sequence which will be correlated with a known bit sequence, also in -1/+1 values. This correlation can easily be performed using a simple integrated circuit (IC).

In addition, an oversampling of the signal received at the RF front end can be performed. For example, the received signal can be expressed with two times oversampling.

This oversampled signal is passed to a fast running AGC to eliminate fast channel fluctuations before the amplitude of the signal is calculated. The amplitude information will be hard quantized. Values larger than the mean amplitude, mean amplitude is 1, will be expressed as +1, values smaller than the mean amplitude will be expressed as -1. This -1/+1 signal is passed to the correlator that performs a cross correlation between the quantized signal and the stored ideal amplitude values of the reference symbol:

amp_sto(k) = 2*bin(k/4),
    if k = 2(oversampling factor) * 2(interpolation factor) * 1,2,3...92
    (92 for 184 reference symbol and interpolation factor 2)
amp_sto(k) = 0, else, k <= 2(oversampling factor) *

2(interpolation factor) * 92
(first part of amp_sto = [0 0 0 -1 0 0 0 1 0 0 0 1 0 0 0 -1 0 .....]).

With this algorithm a correlation maximum of 92 is achievable.

Again, the maxima in the correlator output signal correspond to different frame start positions due to different multipath clusters. In this signal with various maxima the best frame start position has to be chosen. This is done in the following steps: The output of the correlator is given to a threshold detection. If the signal first time exceeds the threshold (a threshold of 50 has proved to be applicable) the best position search algorithm is initialized. The correlator output signal in the interval following the threshold exceeding value will be weighted with the weighting function, see above. The position of the resulting maximum in the weighted signal will be chosen as best frame start position. With the knowledge about the best frame start position the guard interval extraction and the following MCM demodulation will be performed.

Some more efforts can be carried out to increase frame synchronization accuracy. These methods will be explained in the following.

A postprocessing of the frame start decision is performed in order a) to increase the reliability of the frame synchronization; b) to secure that no frame start position is disregarded; and c) to optimize the frame start position in case of varying CIR cluster positions.

Using information of other frame start positions. It is known that in front of each frame a reference symbol is inserted into the signal. If the position of the currently detected frame start has changed significantly regarding the last detected frame start, demodulation of the two frames in total and completely independent from each other is possible. It is also possible to buffer the last signal frame and to perform the required shift of the frame start position step by step with

the MCM symbols of the frame. This results in an interpolative positioning of the single MCM symbols including simultaneous asynchronous guard interval extraction for the different MCM symbols.

Such an interpolative positioning of the FFT window is also possible if one frame start position is missing, i. e. the frame start has not been detected. If one frame start position is missing the guard interval extraction can be performed the same way as in the frame before without large performance degradation. This is due to the normally only slowly varying CIR cluster positions, but only if the signal strength is good enough. Stopping demodulation and waiting for the next detected frame start position is also imaginable but not desirable because of the long interrupt.

What follows is an example of a reference symbol of 184 samples (subcarrier symbols) as provided by the inventive apparatus for generating a signal having a frame structure.

The underlying binary sequence of length 92 is:

```
bin = [0 1 1 0 1 1 0 1 0 1 1 0 1 0 1 0
       0 0 1 1 1 0 0 0 0 0 0 0 0 1 1 0
       1 1 1 1 1 0 0 0 1 1 1 0 0 0 0 0
       0 0 1 1 1 0 1 1 1 0 0 1 1 0 1 1
       1 0 1 1 0 1 0 1 0 1 1 0 1 1 0 1
       1 0 1 0 0 0 0 1 0 1 1 0]
```

The modulated binary sequence is:

```
i_q = [0.5 1.5 1.5 0.5 1.5 1.5 0.5 1.5 0.5 1.5 1.5 0.5 1.5 0.5
       1.5 0.5 0.5 0.5 1.5 1.5 1.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
       0.5 1.5 1.5 0.5 1.5 1.5 1.5 1.5 1.5 0.5 0.5 0.5 1.5 1.5
       1.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1.5 1.5 1.5 0.5 1.5 1.5
       1.5 0.5 0.5 1.5 1.5 0.5 1.5 1.5 1.5 0.5 1.5 1.5 0.5 1.5
       0.5 1.5 0.5 1.5 1.5 0.5 1.5 1.5 0.5 1.5 0.5 1.5 0.5 0.5
       0.5 0.5 1.5 0.5 1.5 1.5 0.5]
```

This modulated binary sequence i_q is interpolated in order to produce an interpolated sequence i_q_int:

```
i_q_int = [0.5000  1.0635  1.5000  1.7195  1.5000  0.8706  0.5000
           0.8571  1.5000  1.7917  1.5000  0.8108  0.5000  1.0392
           1.5000  1.0392  0.5000  0.8108  1.5000  1.7984  1.5000
           0.8108  0.5000  1.0460  1.5000  0.9997  0.5000  0.9603
           1.5000  1.1424  0.5000  0.3831  0.5000  0.4293  0.5000
           0.9997  1.5000  1.5769  1.5000  1.5769  1.5000  1.0065
           0.5000  0.3899  0.5000  0.5325  0.5000  0.4931  0.5000
           0.4999  0.5000  0.4931  0.5000  0.5325  0.5000  0.3967
           0.5000  0.9603  1.5000  1.7522  1.5000  0.8571  0.5000
           0.8965  1.5000  1.6422  1.5000  1.4669  1.5000  1.4737
           1.5000  1.6096  1.5000  0.9929  0.5000  0.4226  0.5000
           0.4226  0.5000  0.9997  1.5000  1.5769  1.5000  1.5769
           1.5000  1.0065  0.5000  0.3899  0.5000  0.5325  0.5000
           0.4931  0.5000  0.4931  0.5000  0.5325  0.5000  0.3899
           0.5000  1.0065  1.5000  1.5701  1.5000  1.6096  1.5000
           0.8965  0.5000  0.8965  1.5000  1.6096  1.5000  1.5633
           1.5000  1.0392  0.5000  0.2867  0.5000  0.9929  1.5000
           1.7454  1.5000  0.8571  0.5000  0.9033  1.5000  1.6028
           1.5000  1.6028  1.5000  0.9033  0.5000  0.8503  1.5000
           1.7917  1.5000  0.8108  0.5000  1.0460  1.5000  0.9929
           0.5000  0.9929  1.5000  1.0460  0.5000  0.8108  1.5000
           1.7917  1.5000  0.8571  0.5000  0.8571  1.5000  1.7849
           1.5000  0.8571  0.5000  0.8571  1.5000  1.7917  1.5000
           0.8176  0.5000  1.0065  1.5000  1.1424  0.5000  0.3436
           0.5000  0.5788  0.5000  0.3436  0.5000  1.1424  1.5000
           1.0065  0.8312  1.5000  1.7263  1.5000  1.0635  0.5000
           0.0637]
```

amp_int = i_q_int + j*i_q_int

amp_int is the reference symbol inserted periodically into the signal after the guard interval insertion.

As it is clear from the above specification, the present invention provides methods and apparatus for generating a signal having a frame structure and methods and apparatus for

frame synchronization when receiving such signals which are superior when compared with prior art systems. The frame synchronization algorithm in accordance with the present invention provides all of the properties shown in Table 1 in contrary to known frame synchronization procedures. Table 1 shows a comparison between the system in accordance with the present invention using an AM sequence as reference symbol and prior art systems (single carrier and MCM Eureka 147).

Table 1

	single carrier (e.g. QPSK like WS)	MCM Eureka 147	MCM with AM sequence
carrier offset allowed	no	yes	yes
constant power achieved at Rx input	yes	no	yes
coarse frequency offset estimation possible	no	no	yes
coarse channel estimation possible (cluster estimation)	yes	no	yes

As can be seen from Table 1 different synchronization tasks and parameters can be derived using the frame synchronization with an AM sequence in accordance with the present invention. The frame synchronization procedure MCM Eureka 147 corresponds to the procedure described in US-A-5,191,576.

CLAIMS

1. A method for generating a signal having a frame structure, each frame of said frame structure comprising at least one useful symbol (12), a guard interval (14) associated to said at least one useful symbol (12) and a reference symbol (16), said method comprising the step of

   performing an amplitude modulation of a bit sequence such that the envelope of the amplitude modulated bit sequence defines a reference pattern of said reference symbol (16).

2. The method according to claim 1, wherein said signal is an orthogonal frequency division multiplexed signal.

3. The method according to claim 1 or 2, wherein said amplitude modulation is performed such that a mean amplitude of said reference symbol (16) substantially corresponds to a mean amplitude of the remaining signal.

4. A method for generating a multi-carrier modulated signal having a frame structure, each frame of said frame structure comprising at least one useful symbol (12), a guard interval (14) associated to said at least one useful symbol (12) and a reference symbol (16), said method comprising the steps of:

   providing a bitstream (104);

   mapping bits of said bitstream (104) to carriers in order to provide a sequence of spectra (108);

   performing an inverse Fourier transform (110) in order to provide multi-carrier modulated symbols (112);

   associating (114) a guard interval to each multi-carrier modulated symbol;

   generating said reference symbol (16) by performing an

amplitude modulation of a bit sequence such that the envelope of the amplitude modulated bit sequence defines a reference pattern of said reference symbol; and

associating (116) said reference symbol (16) to a predetermined number of multi-carrier modulated symbols and associated guard intervals in order to define said frame.

5. The method according to claim 4, wherein said multi-carrier modulated signal is an orthogonal frequency division multiplex signal.

6. The method according to claim 4 or 5, wherein said amplitude modulation is performed such that a mean amplitude of said reference symbol (16) substantially corresponds to a mean amplitude of the remaining multi-carrier modulated signal.

7. The method according to one of claims 1 to 6, wherein said bit sequence is a pseudo random bit sequence having good autocorrelation characteristics.

8. The method according to one of claims 1 to 7, wherein a number of useful symbols (12) in each frame is defined depending on channel properties of a channel (122) through which the signal or the multi-carrier modulated signal is transmitted.

9. A method for frame synchronization of a signal having a frame structure, each frame of said frame structure comprising at least one useful symbol (12), a guard interval (14) associated with said at least one useful symbol (12) and a reference symbol (16), said method comprising the steps of:

receiving said signal;

down-converting said received signal;

performing (164) an amplitude-demodulation of said down-converted signal in order to generate an envelope;

correlating (166) said envelope with a predetermined reference pattern in order to detect a signal reference pattern of said reference symbol (16) in said signal; and

performing said frame synchronization based on the detection of said signal reference pattern.

10. The method according to claim 9, further comprising the step of performing a fast automatic gain control (162) of said received down-converted signal prior to the step of performing said amplitude-demodulation (164).

11. The method according to claim 9 or 10, wherein the step of performing (164) said amplitude-demodulation comprises the step of calculating an amplitude of said signal using the $alpha_{max+}$ $beta_{min-}$ method.

12. The method according to claim 9 or 10, further comprising the steps of sampling respective amplitudes of said received down-converted signal and comparing said sampled amplitudes with a predetermined threshold in order to generate a bit sequence in order to perform said amplitude demodulation.

13. The method according to claim 12, wherein the step of sampling respective amplitudes of said received down-converted signal further comprises the step of performing an over-sampling of said received down-converted signal.

14. The method according to any one of claims 9 to 13, further comprising the step of applying a result of the frame synchronization for a frame in said signal to at least one subsequent frame in said signal.

15. A method for frame synchronization of a multi-carrier

modulated signal having frame structure, each frame of said frame structure comprising at least one useful symbol (12), a guard interval (14) associated to said at least one useful symbol (12) and a reference symbol (16), said method comprising the steps of:

receiving said multi-carrier modulated signal;

down-converting said received multi-carrier modulated signal;

performing (164) an amplitude-demodulation of said down-converted multi-carrier modulated signal in order to generate an envelope;

correlating (166) said envelope with a predetermined reference pattern in order to detect a signal reference pattern of said reference symbol in said multi-carrier modulated signal;

performing said frame synchronization based on the detection of said signal reference pattern;

extracting (136/138) said reference symbol (16) and said at least one guard interval (14) from said down-converted received multi-carrier modulated signal based on said frame synchronization;

performing (140) a Fourier transform in order to provide a sequence of spectra from said at least one useful symbol;

de-mapping (142) said sequence of spectra in order to provide a bitstream.

16. The method according to claim 15, further comprising the step of performing (162) a fast automatic gain control of said received down-converted multi-carrier modulated signal prior to the step of performing said amplitude-demodulation.

17. The method according to claim 15 or 16, wherein the step of performing (164) said amplitude-demodulation comprises the step of calculating an amplitude of said multi-carrier modulated signal using the alpha_{max+} beta_{min-} method.

18. The method according to claim 15 or 16, further comprising the steps of sampling respective amplitudes of said received down-converted multi-carrier modulated signal and comparing said sampled amplitudes with a predetermined threshold in order to generate a bit sequence in order to perform said amplitude demodulation.

19. The method according to claim 18, wherein the step of sampling respective amplitudes of said received down-converted multi-carrier modulated signal further comprises the step of performing an over-sampling of said received down-converted multi-carrier modulated signal.

20. The method according to one of claims 15 to 19, further comprising the step of applying a result of the frame synchronization for a frame in said signal to at least one subsequent frame in said multi-carrier modulated signal.

21. The method according to one of claims 9 to 20, further comprising the step of detecting a location of said signal reference pattern based on an occurrence of a maximum of a correlation signal when correlating said envelope with said predetermined reference pattern.

22. The method according to claim 21, further comprising the steps of:

weighting a plurality of maxima of said correlation signal such that a maximum occurring first is weighted stronger than any subsequently occurring maximum; and

detecting said location of said signal reference pattern based on the greatest one of said weighted maxima.

23. The method according to claim 22, further comprising the step of:

disabling the step of performing said frame synchronization for a predetermined period of time after having switched-on a receiver (130) performing said method for frame synchronization.

24. An apparatus for generating a signal having a frame structure, each frame of said frame structure comprising at least one useful symbol (12), a guard interval (14) associated to said at least one useful symbol (12) and a reference symbol (14), said apparatus comprising:

an amplitude modulator for performing an amplitude modulation of a bit sequence such that the envelope of the amplitude modulated bit sequence defines a reference pattern of said reference symbol (16).

25. The apparatus according to claim 24, wherein said signal is an orthogonal frequency division multiplexed signal.

26. The apparatus according to claim 24 or 25, wherein a mean amplitude of said reference symbol (16) substantially corresponds to a mean amplitude of the remaining signal.

27. An apparatus for generating a multi-carrier modulated signal having a frame structure, each frame of said frame structure comprising at least one useful symbol (12), a guard interval (14) associated to said at least one useful symbol (12) and a reference symbol (16), said apparatus comprising:

means (102) for providing a bitstream (104);

means (106) for mapping bits of said bitstream (104) to carriers in order to provide a sequence of spectra (108);

means (110) for performing an inverse Fourier transform in order to provide multi-carrier modulated symbols (112);

means (114) for associating a guard interval to each multi-carrier modulated symbol;

means for generating said reference symbol (16) comprising an amplitude modulator for performing an amplitude modulation of a bit sequence such that the envelope of the amplitude modulated bit sequence defines a reference pattern of said reference symbol (16); and

means (116) for associating said reference symbol (16) to a predetermined number of multi-carrier modulated symbols (12) and associated guard intervals (14) in order to define said frame.

28. The apparatus according to claim 27, wherein said multi-carrier modulated signal is an orthogonal frequency division multiplex signal.

29. The apparatus according to claim 26 or 27, wherein said means for generating said reference symbol (16) performs the amplitude modulation such that a mean amplitude of said reference symbol (16) substantially corresponds to a mean amplitude of the remaining multi-carrier modulated signal.

30. The apparatus according to one of claims 24 to 29, wherein said means for generating said reference symbol (16) generates a pseudo random bit sequence having good autocorrelation characteristics as said bit sequence.

31. The apparatus according to one of claims 24 to 30, comprising means for determining a number of useful symbols (12) in each frame depending on channel properties of a channel (122) through which the signal or the multi-carrier modulated signal is transmitted.

32. An apparatus for frame synchronization of a signal having a

frame structure, each frame of said frame structure comprising at least one useful symbol (12), a guard interval (14) associated to said at least one useful symbol (12) and a reference symbol (16), said apparatus comprising:

receiving means (150) for receiving said signal;

a down-converter for down-converting said received signal;

an amplitude-demodulator (164) for performing an amplitude demodulation of said down-converted signal in order to generate an envelope;

a correlator (166) for correlating said envelope with a predetermined reference pattern in order to detect a signal reference pattern of said reference symbol (16) in said signal; and

means for performing said frame synchronization based on the detection of said signal reference pattern.

33. The apparatus according to claim 32, further comprising means (162) for performing a fast automatic gain control of said received down-converted signal preceding said amplitude-demodulator (164).

34. The apparatus according to claim 32 or 33, wherein said amplitude-demodulator (164) comprises means for calculating an amplitude of said signal using the $alpha_{max+}$ $beta_{min-}$ method.

35. The apparatus according to claim 32 or 33, further comprising means for sampling respective amplitudes of said received down-converted signal, wherein said amplitude-demodulator (164) comprises means for comparing said sampled amplitudes with a predetermined threshold in order to generate a bit sequence.

36. The apparatus according to claim 35, wherein said means for sampling comprises means for over-sampling said received down-converted signal.

37. The apparatus according to one of claims 32 to 36, further comprising means for applying a result of the frame synchronization for a frame in said signal to at least one subsequent frame in said signal.

38. An apparatus for frame synchronization of a multi-carrier modulated signal having a frame structure, each frame of said frame structure comprising at least one useful symbol (12), a guard interval (14) associated to said at least one useful symbol (12) and a reference symbol (16), said apparatus comprising:

a receiver (150) for receiving said multi-carrier modulated signal;

a down-converter for down-converting said received multi-carrier modulated signal;

an amplitude-demodulator (164) for performing an amplitude-demodulation of said down-converted multi-carrier modulated signal in order to generate an envelope;

a correlator (166) for correlating said envelope with a predetermined reference pattern in order to detect a signal reference pattern of said reference symbol (16) in said multi-carrier modulated signal;

means for performing said frame synchronization based on the detection of said signal reference pattern;

means (136/138) for extracting said reference symbol (16) and said at least one guard interval (14) from said down-converted received multi-carrier modulated signal based on said frame synchronization in order to generate said at least one useful symbol;

means (140) for performing a Fourier transform in order to provide a sequence of spectra from said at least one useful symbol; and

means (142) for de-mapping said sequence of spectra in order to provide a bitstream.

39. The apparatus according to claim 38, further comprising means (162) for performing a fast automatic gain control of said received down-converted multi-carrier modulated signal preceding said amplitude-demodulator (164).

40. The apparatus according to claim 38 or 39, wherein said amplitude-demodulator (164) comprises means for calculating an amplitude of said multi-carrier modulated signal using the $alpha_{max+}$ $beta_{min-}$ method.

41. The apparatus according to claim 38 or 39, further comprising means for sampling respective amplitudes of said received down-converted multi-carrier modulated signal, wherein said amplitude-demodulator (164) comprises means for comparing said sampled amplitudes with a predetermined threshold in order to generate a bit sequence.

42. The apparatus according to claim 41, wherein said means for sampling comprises means for over-sampling said received down-converted multi-carrier modulated signal.

43. The apparatus according to one of claims 38 to 42, further comprising means for applying a result of the frame synchronization for a frame in said multi-carrier modulated signal to at least one subsequent frame in said multi-carrier modulated signal.

44. The apparatus according to one of claims 32 to 43, further comprising means for detecting a location of said signal reference pattern based on an occurrence of a maximum of a correlation signal output of said correlator (166).

45. The apparatus according to claim 44, further comprising means for weighting a plurality of maxima of said correlation signal such that a maximum occurring first is weighted stronger than any subsequently occurring maximum; and

means for detecting said location of said signal reference pattern based on the greatest one of said weighted maxima.

46. The apparatus according to claim 45, further comprising means for disabling said means for performing said frame synchronization for a predetermined period of time after having switched-on a receiver (130) comprising said apparatus for frame synchronization.

METHOD AND APPARATUS FOR GENERATING A SIGNAL HAVING A FRAME STRUCTURE AND METHOD AND APPARATUS FOR FRAME SYNCHRONIZATION

ABSTRACT

A method for generating a signal having a frame structure, each frame of the frame structure comprising at least one useful symbol (12), a guard interval (14) associated to the at least one useful symbol (12) and a reference symbol (16), comprises the step of performing an amplitude modulation of a bit sequence such that the envelope of the amplitude modulated bit sequence defines a reference pattern of the reference symbol (16). A method for frame synchronization of a signal having such a frame structure comprises the steps of receiving the signal, down-converting the received signal, performing (164) an amplitude-demodulation of the down-converted signal in order to generate an envelope, correlating (166) the envelope with a predetermined reference pattern in order to detect a signal reference pattern of the reference symbol (16) in the signal, and performing the frame synchronization based on the detection of the signal reference pattern.

09/673271

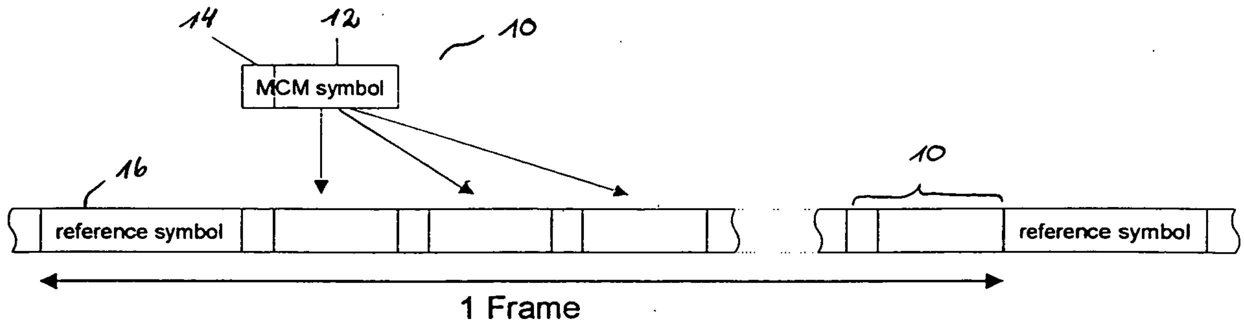

Fig. 1

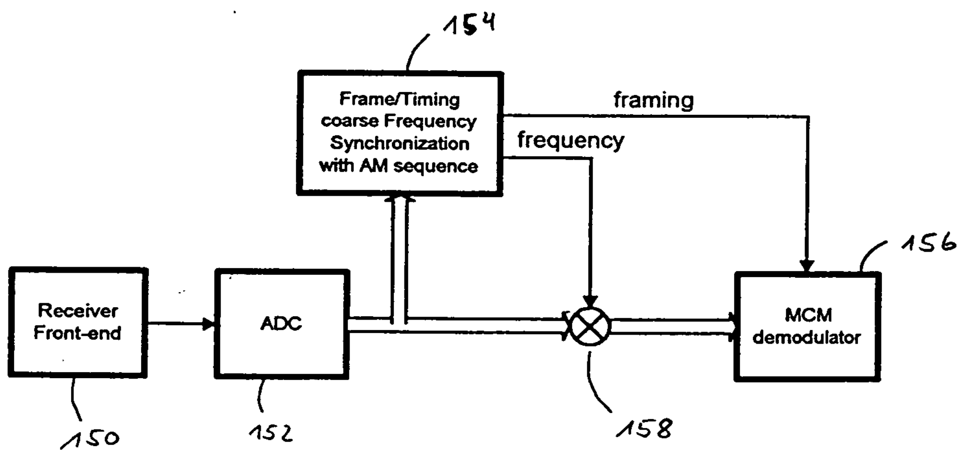

Fig. 3

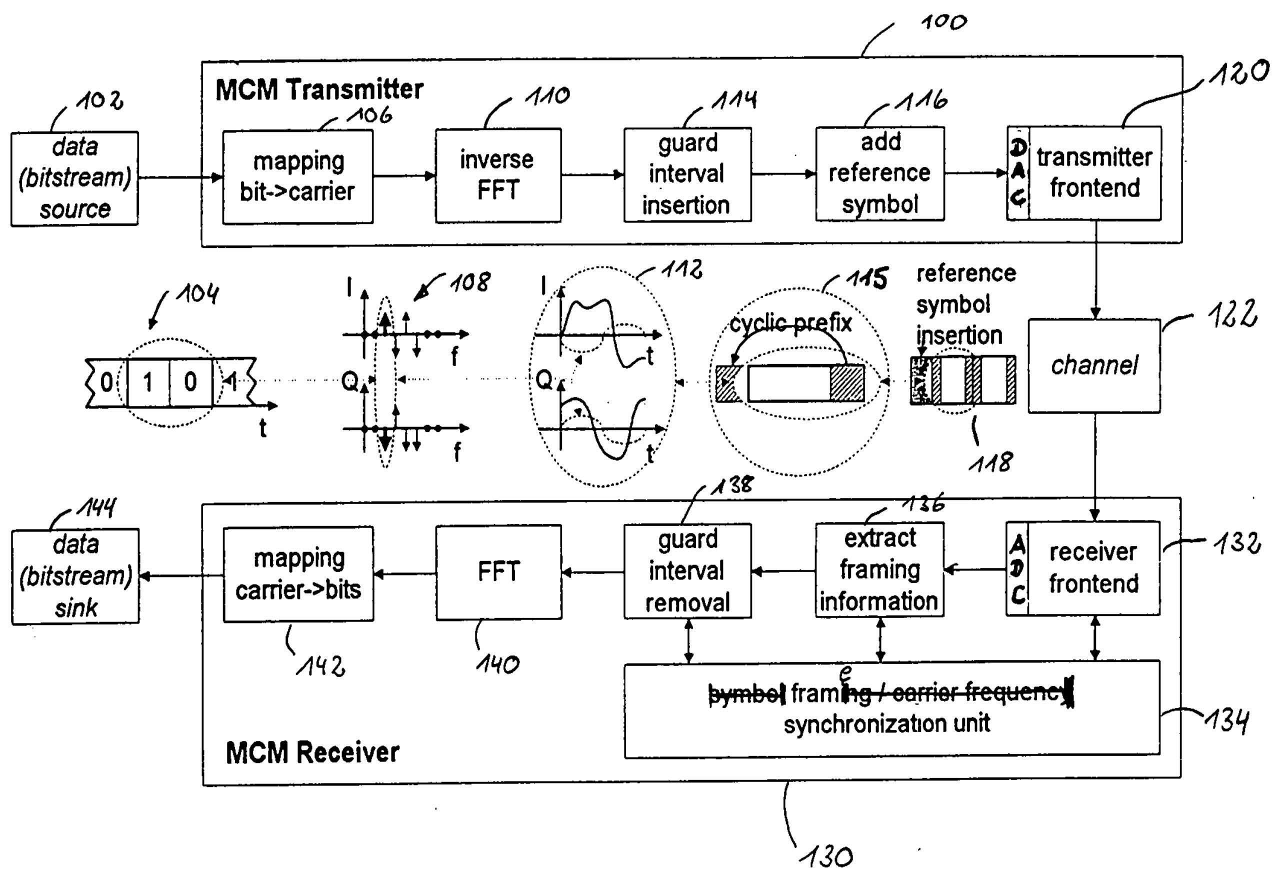

Fig. 2

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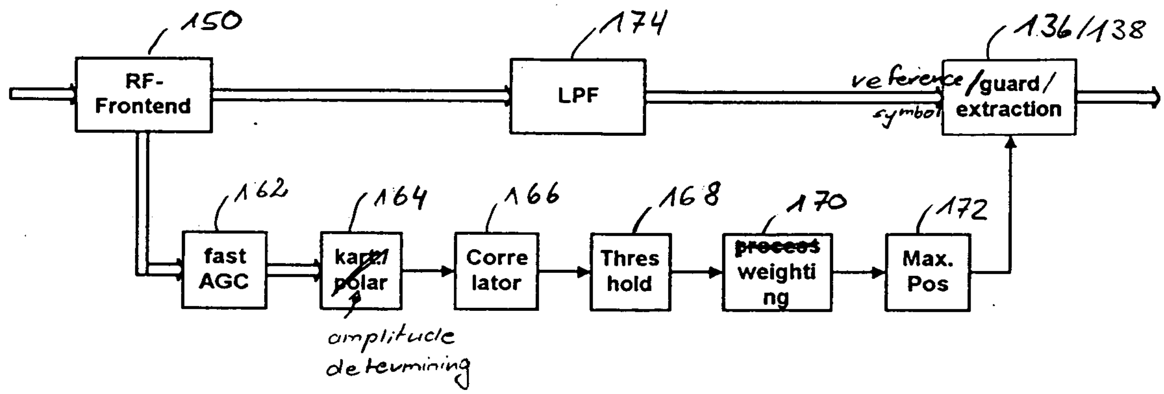

Fig. 4

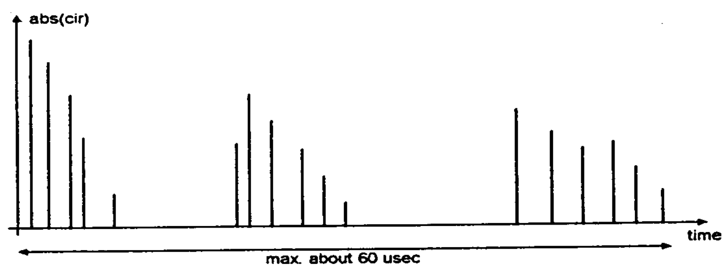

Fig. 5

TENT COOPERATION TREAT

.ne
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Schoppe, F.
SCHOPPE, ZIMMERMANN & STÖCKELER
Postfach 71 08 67
D-81458 München
ALLEMAGNE

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(PCT Rule 71.1)

Date of mailing *(day/month/year)*	09.02.00
Applicant's or agent's file reference FH980402PCT	**IMPORTANT NOTIFICATION**

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/EP98/02169	14/04/1998	14/04/1998

Applicant
FRAUHNOFER-GESELLSCHAFT ZUR FÖRDERUNG .....et al.

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

   The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

   Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

   For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/	Authorized officer
European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Ahrens, R Tel.+49 89 2399-8136

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INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference FH980402PCT	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/EP98/02169	International filing date *(day/month/year)* 14/04/1998	Priority date *(day/month/year)* 14/04/1998
International Patent Classification (IPC) or national classification and IPC H04L27/26		
Applicant FRAUHNOFER-GESELLSCHAFT ZUR FÖRDERUNG .....et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 6 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 26 sheets.

3. This report contains indications relating to the following items:

   I ☒ Basis of the report
   II ☐ Priority
   III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   IV ☐ Lack of unity of invention
   V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   VI ☐ Certain documents cited
   VII ☐ Certain defects in the international application
   VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
22/07/1999	09.02.00
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Dechmann, J-L Telephone No. +49 89 2399 8826

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/EP98/02169

I. Basis of the report

1. This report has been drawn on the basis of (*substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.*):

Description, pages:

1-3,11-17,22-25	as originally filed			
4-10,10a-10b, 18-21	as received on	24/01/2000	with letter of	24/01/2000

Claims, No.:

1-46	as received on	24/01/2000	with letter of	24/01/2000

Drawings, sheets:

1/3	as originally filed			
2/3,3/3	as received on	24/01/2000	with letter of	24/01/2000

2. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:
- ☐ the drawings, sheets:

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

4. Additional observations, if necessary:

INTERNATIONAL PRELIMINARY
EXAMINATION REPORT

International application No. PCT/EP98/02169

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-46
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-46
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-46
	No:	Claims	

2. Citations and explanations

see separate sheet

V. Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement

I

The following documents have been considered for the purposes of this report:

D1: EP-A-0 631 406
D2: WO-A-98 00946 A
D3: IEEE TRANSACTIONS ON COMMUNICATIONS., vol. 42, no. 10, October 1994, pages 2908-2914, XP002019915
D4: IEEE INTERNATIONAL SYMPOSIUM ON PERSONAL, INDOOR AND MOBILE RADIO COMMUNICATIONS, 15 October 1996, pages 963-967, XP002063294

II

The present application relates to methods (ind. cl. 1 and 4) and apparatus (ind. cl. 24 and 27) for generating a signal having a frame structure, wherein each frame of the frame structure is composed of useful symbols, a guard interval and one reference symbol. In addition, the present invention relates to methods (ind. cl. 9 and 15) and apparatus (ind. cl. 32 and 38) for frame synchronisation of signals having the above structure.

The following problem occurs in the receiver: the exact position of the guard interval and hence the position of the original useful parts of the time domain symbols is generally unknown. Extraction of the guard interval and the subsequent FFT-transform of the resulting useful part of the time signal is not possible without additional information. To provide this additional information, a known (single carrier) sequence in the form of a (time domain) reference symbol is inserted into the time signal. With the

knowledge about the positions of the reference symbols in the received signal, the exact positions of the guard intervals and thus the interesting information carrying time samples are known.

The methods for frame synchronization available up to date require either prior achieved frequency synchronization or become very complex when the signal in the receiver is corrupted by a large frequency offset.
If there is a frequency offset in the receiver, as can easily be the case when a receiver is powered-on and the frequency synchronization loop is not yet locked, problems will occur. When performing a simple correlation there will only be noise at the output of the correlator , i.e. no maximum can be found if the frequency offset exceeds a certain bound. The size of the frequency offset depends on the length (time) of the correlation to be performed, i.e. the longer it takes, the smaller the allowed frequency offset becomes. In general frequency offset increases implementation complexity.

It is an object of the present invention to provide a method and an apparatus for generating a signal having a frame structure that allow a frame synchronization after the signals have been transmitted even in the case of a carrier frequency offset or in the case of a transmission via a multipath fading channel.

The invention relates to a method for finding frame headers independently of other synchronization information and thus for positioning the FFT windows correctly. This includes the extraction of a guard interval. The method is based on the detection of a known reference symbol of the frame header in the reception signal, e.g. in the digital complex baseband. The new frame synchronization will be performed as the first synchronization task.

Synchronization to the reference symbol, i.e. the frame header is the first step to initiate radio reception. The reference symbol is structured to accomplish this. The information contained in the reference symbol must therefore be independent of other synchronization parameters, e.g. frequency offset. For this reason, in accordance with the present invention, the form of the reference symbol selected is an **amplitude modulated** sequence (AM sequence) in the complex baseband. **Thus, the information contained in the reference symbol is only that given in the amplitude and not that in the phase.** Note that the phase information will be corrupted by a

possible frequency offset.
In the receiver, the first step after the down-conversion of the received signal is to perform an amplitude-demodulation of the down-converted signal in order to generate an envelope, i.e. in order to determine the amplitude of the signal. This envelope is correlated with a replica reference pattern in order to detect the signal reference pattern of the reference symbol in the signal.
Thus, the present invention shows how to find a reference symbol by a detection method which is simple. Furthermore, the present invention can be used for one-carrier or multi-carrier systems. The present invention is particularly useful in multi-carrier modulation systems using an orthogonal frequency division multiplexing, for example in the field of digital broadcasting. The synchronisation methods according to the present invention are independent of other synchronisation steps. Since the information needed for the synchronisation is contained in the enveloped of the preamble, i.e. the reference symbol, the reference symbol is independent of possible frequency offsets. Thus, a derivation of the correct down sampling timing and the correct positioning of the FFT window can be achieved. The reference symbol of the present invention can be detected even if the frequency synchronisation loop is not yet locked or even in the case of a carrier frequency offset. The frame synchronisation method in accordance with the present invention is preferably performed prior to other and without knowledge of other synchronisation efforts.
Such a solution is neither disclosed nor suggested by the cited documents and an inventive step is acknowledged. Claims 1-46 therefore fulfill the requirements of Article 33(3) PCT.

Vehic. Technology Conference, 1997; Schmidl, T.M., Cox, D.C.: Low-Overhead, Low-Complexity [Burst] Synchronization for OFDM Transmission, *Proc. IEEE Int. Conf. on Commun.*, 1996. In such systems, the receiver's processor looks for a periodic repetition. For these algorithms coarse frequency synchronization has to be achieved prior to or at least simultaneously with frame synchronization.

Van de Beek, J, Sandell, M., Isaksson, M, Börjesson, P.: Low-Complex Frame Synchronization in OFDM Systems, *Proc. of the ICUPC*, 1995, avoid the insertion of additional reference symbols or pilot carriers and use instead the periodicity in the MCM signal which is inherent in the guard interval and the associated cyclical extension. This method is suitable only for slowly varying fading channels and small frequency offsets.

US-A-5,191,576 relates to a method for the diffusion of digital data designed to be received notably by mobile receivers moving in an urban environment. In this method, the header of each frame of a broadcast signal having a frame structure has a first empty synchronization symbol and a second unmodulated wobbled signal forming a two-stage analog synchronization system. The recovery of the synchronization signal is achieved in an analog way, without prior extraction of a clock signal at the binary level.

EP 0631406 A relates to data signals, COFDM signals, for example, and to methods and apparatus for diffusing said signals. The COFDM signals comprises a sequence of symbols, each symbol having an useful portion and a guard interval. Two symbols of a COFDM signal are provided as synchronization symbols. One of the two symbols is a zero symbol, whereas the other thereof is a synchronization symbol which is formed by an unmodulated multiplex of the carrier frequencies having a constant envelope. Beside the two symbols as synchronization symbols, it is taught in EP 0631406 A to modulate the pilot frequency of the data signal with a reference signal which carries the synchronization information. This reference signal modulated on the pilot frequency of the data signal can be used

by a MABLR demodulator.

WO 98/00946 A relates to a system for a timing and frequency synchronization of OFDM signals. Two OFDM training symbols are used to obtain full synchronization in less than two data frames. The OFDM training symbols are placed into the OFDM signal, preferably at least once every frame. The first OFDM training symbol is produced by modulating the even-numbered OFDM sub-carriers whereas the odd-numbered OFDM sub-carriers are suppressed. Thus, in accordance with WO 98/00946 A, the first OFDM training symbol is produced by modulating the even-numbered carriers of this symbol with a first predetermined PN sequence.

Moose: "A technique for orthogonal frequency division multiplexing frequency offset correction", IEEE TRANSACTIONS ON COMMUNICATIONS, Vo. 42, No. 10, October 1994, pages 2908 to 2914, teaches methods for correcting frequency offsets in OFDM digital communications. The methods involve repetition of a data symbol and comparison of the phases of each of the carriers between the successive symbols. The phase shift of each of the carriers between the repeated symbols is due to the frequency offset since the modulation phase values are not changed in the repeated symbols.

Keller; Hanzo: "Orthogonal frequency division multiplex synchronization techniques for wireless local area networks", IEEE INTERNATIONAL SYMPOSIUM ON PERSONAL, INDOOR AND MOBILE RADIO COMMUNICATIONS, October 15, 1996, pages 963 to 967, teach frequency acquisition, frequency tracking, symbol synchronization and frame synchronization techniques. Regarding the frame synchronization, it is taught to use a reference symbol which consists of repetitive copies of a synchronization pattern of pseudo-random samples. The frame synchronization is achieved by autocorrelation techniques using the periodic synchronization segments such that for the synchronization algorithms proposed no a priori knowledge of the synchronization sequences is required.

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The methods for frame synchronization available up to date require either prior achieved frequency synchronization or become very complex when the signal in the receiver is corrupted by a large frequency offset.

If there is a frequency offset in the receiver, as can easily be the case when a receiver is powered-on and the frequency synchronization loop is not yet locked, problems will occur. When performing a simple correlation there will only be noise at the output of the correlator , i.e. no maximum can be found if the frequency offset exceeds a certain bound. The size of the frequency offset depends on the length (time) of the correlation to be performed, i.e. the longer it takes, the smaller the allowed frequency offset becomes. In general, frequency offset increases implementation complexity.

Frequency offsets occur after power-on or later due to frequency deviation of the oscillators used for down-conversion to baseband. Typical accuracies for the frequency of a free running local oscillator (LO) are at ±50 ppm of the carrier frequency. With a carrier frequency in S-band (e.g. 2.34 GHz) there will be a maximum LO frequency deviation of above 100 kHz (117.25 kHz). A deviation of this magnitude puts high demands on the above methods.

In the case of multipath impaired transmission channel, a correlation method yields several correlation maxima in addition to the distinct maximum for an AWGN channel. The best possible frame header position, i.e. the reference symbol, has to be selected to cope with this number of maxima. In multipath channels, frame synchronization methods with correlations can not be used without major changes. Moreover, it is not possible to use data demodulated from the MCM system, because the demodulation is based on the knowledge of the position of the guard interval and the useful part of the MCM symbol.

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SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method and an apparatus for generating a signal having a frame structure that allow a frame synchronization after the signals have been transmitted even in the case of a carrier frequency offset or in the case of a transmission via a multipath fading channel.

It is a further object of the present invention to provide a method and an apparatus for frame synchronization of a signal having a frame structure even in the case of a carrier frequency offset.

In accordance with a first aspect, the present invention provides a method for generating a signal having a frame structure, each frame of the frame structure comprising at least one useful symbol, a guard interval associated to the at least one useful symbol and a reference symbol, the method comprising the steps of performing an amplitude modulation of a bit sequence, the envelope of the amplitude modulated bit sequence defining the reference pattern of the reference symbol and inserting the amplitude modulated bit sequence into said signal as said reference symbol.

In accordance with a second aspect, the present invention provides a method for generating a multi-carrier modulated signal having a frame structure, each frame of the frame structure comprising at least one useful symbol, a guard interval associated to the at least one useful symbol and a reference symbol, the method comprising the steps of:

providing a bitstream;

mapping bits of the bitstream to carriers in order to provide a sequence of spectra;

performing an inverse Fourier transform in order to provide multi-carrier modulated symbols;

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associating a guard interval to each multi-carrier modulated symbol;

generating the reference symbol by performing an amplitude modulation of a bit sequence, the envelope of the amplitude modulated bit sequence defining the reference pattern of the reference symbol;

associating the reference symbol to a predetermined number of multi-carrier modulated symbols and associated guard intervals in order to define the frame; and

inserting said amplitude modulated bit sequence into said signal as said reference symbol.

In accordance with a third aspect, the present invention provides a method for frame synchronization of a signal having a frame structure, each frame of the frame structure comprising at least one useful symbol, a guard interval associated with the at least one useful symbol and a reference symbol, the method comprising the steps of:

receiving the signal;

down-converting the received signal;

performing an amplitude-demodulation of the down-converted signal in order to generate an envelope;

correlating the envelope with a predetermined reference pattern in order to detect the signal reference pattern of the reference symbol in the signal; and

performing the frame synchronization based on the detection of the signal reference pattern.

In accordance with a fourth aspect, the present invention provides a method for frame synchronization of a multi-carrier

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modulated signal having frame structure, each frame of the frame structure comprising at least one useful symbol, a guard interval associated to the at least one useful symbol and a reference symbol, the method comprising the steps of:

receiving the multi-carrier modulated signal;

down-converting the received multi-carrier modulated signal;

performing an amplitude-demodulation of the down-converted multi-carrier modulated signal in order to generate an envelope;

correlating the envelope with a predetermined reference pattern in order to detect the signal reference pattern of the reference symbol in the multi-carrier modulated signal;

performing the frame synchronization based on the detection of the signal reference pattern;

extracting the reference symbol and the at least one guard interval from the down-converted received multi-carrier modulated signal based on the frame synchronization;

performing a Fourier transform in order to provide a sequence of spectra from the at least one useful symbol;

de-mapping the sequence of spectra in order to provide a bitstream.

In accordance with a fifth aspect, the present invention provides an apparatus for generating a signal having a frame structure, each frame of the frame structure comprising at least one useful symbol, a guard interval associated to the at least one useful symbol and a reference symbol, the apparatus comprising an amplitude modulator for performing an amplitude modulation of a bit sequence, the envelope of the amplitude modulated bit sequence defining the reference pattern of the

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reference symbol; and

means for inserting the amplitude modulated bit sequence into said signal as said reference symbol.

In accordance with a sixth aspect, the present invention provides an apparatus for generating a multi-carrier modulated signal having a frame structure, each frame of the frame structure comprising at least one useful symbol, a guard interval associated to the at least one useful symbol and a reference symbol, the apparatus comprising:

means for providing a bitstream;

means for mapping bits of the bitstream to carriers in order to provide a sequence of spectra;

means for performing an inverse Fourier transform in order to provide multi-carrier modulated symbols;

means for associating a guard interval to each multi-carrier modulated symbol;

means for generating the reference symbol by an amplitude modulator for performing an amplitude modulation of a bit sequence, the envelope of the amplitude modulated bit sequence defining the reference pattern of the reference symbol;

means for associating the reference symbol to a predetermined number of multi-carrier modulated symbols and associated guard intervals in order to define the frame; and

means for inserting the amplitude modulated bit sequence into said signal as said reference symbol.

In accordance with a seventh aspect, the present invention provides an apparatus for frame synchronization of a signal

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having a frame structure, each frame of the frame structure comprising at least one useful symbol, a guard interval associated to the at least one useful symbol and a reference symbol, the apparatus comprising:

receiving means for receiving the signal;

a down-converter for down-converting the received signal;

an amplitude-demodulator for performing an amplitude demodulation of the down-converted signal in order to generate an envelope;

a correlator for correlating the envelope with a predetermined reference pattern in order to detect the signal reference pattern of the reference symbol in the signal; and

means for performing the frame synchronization based on the detection of the signal reference pattern.

In accordance with a eighth aspect, the present invention provides an apparatus for frame synchronization of a multi-carrier modulated signal having a frame structure, each frame of the frame structure comprising at least one useful symbol, a guard interval associated to the at least one useful symbol and a reference symbol, the apparatus comprising:

a receiver for receiving the multi-carrier modulated signal;

a down-converter for down-converting the received multi-carrier modulated signal;

an amplitude-demodulator for performing an amplitude-demodulation of the down-converted multi-carrier modulated signal in order to generate an envelope;

a correlator for correlating the envelope with a

→ page 10b

predetermined reference pattern in order to detect the signal reference pattern of the reference symbol in the multi-carrier modulated signal;

means for performing the frame synchronization based on the detection of the signal reference pattern;

means for extracting the reference symbol and the at least one guard interval from the down-converted received multi-carrier modulated signal based on the frame synchronization in order to generate the at least one useful symbol;

means for performing a Fourier transform in order to provide a sequence of spectra from the at least one useful symbol; and

means for de-mapping the sequence of spectra in order to provide a bitstream.

The present invention provides a novel structure of the reference symbol along with a method to determine the position of the reference symbol and thus the start of a frame in a signal having a frame structure as shown for example in Figure 1.

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signal transmitted through the channel 122 is received at the receiver front end 132. The down-converted MCM signal is sampled at the receiver front end 132 and is, in the preferred embodiment, provided to a fast running automatic gain control (time constant < MCM symbol duration) in order to eliminate fast channel fluctuations (channel coherence time ≈ MCM symbol duration). The fast AGC 162 is used in addition to the normally slow AGC in the signal path, in the case of transmission over a multipath channel with long channel impulse response and frequency selective fading. The fast AGC adjusts the average amplitude range of the signal to the known average amplitude of the reference symbol. The so processed symbol is provided to an amplitude determining unit 164.

The amplitude determining unit 164 can use the simple $alpha_{max+}$ $beta_{min-}$ method in order to calculate the amplitude of the signal. This method is described for example in Palachels A.: DSP-mP Routine Computes Magnitude, EDN, October 26, 1989; and Adams, W. T., and Bradley, J.: Magnitude Approximations for Microprocessor Implementation, IEEE Micro, Vol. 3, No. 5, October 1983.

The output signal of the amplitude determining unit 164 is applied to a correlator 166. In the correlator 166, a cross correlation between the amplitude signal output from the amplitude determining unit 164 and a known ideal amplitude information is computed. The known ideal amplitude information is stored in the correlator. For both, the amplitude and the known ideal amplitude information, their amplitudes are symmetrically to zero relative to their average amplitude.

In the ideal AWGN case, the result will be a white noise signal with zero mean value and with a clearly visible positive maximum. In this ideal AWGN case, the position of the single maximum is evaluated in a maximum position unit 172. On the basis of this evaluation, the reference symbol and the guard intervals are extracted from the MCM signal in a combined reference symbol/guard extraction unit 136/138. Although these units are shown as a combined unit 136/138 in Figure 4, it is

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clear that separate units can be provided. The MCM signal is transmitted from the RF front end 150 to the reference symbol/guard extraction unit 136/138 via a low pass filter 174.

In the case of time spreading encountered in a multipath channel, several maxima corresponding to the number of clusters in the channel impulse response occur in the output signal of the correlator. A schematic view of three such clusters located in a time window of maximum about 60 microseconds is shown in Figure 5. Out of the several maxima caused by the time spreading encountered in a multipath channel, the best one has to be selected as the position of the frame header, i.e. the reference symbol. Therefore, a threshold unit 168 and a weighting unit 170 are provided between the correlator 166 and the maximum position unit 172. The threshold unit 168 is provided to remove maxima having an amplitude below a predetermined threshold. The weighting unit 164 is provided in order to perform a weighting procedure on the remaining maxima such that the maximum corresponding to the reference symbol can be determined. An examplary weighting procedure performed in the weighting unit 170 is as follows.

The first significant maximum is considered to be the best one. The output signal of the correlator is observed from the first detected maximum onwards for the maximum length of the channel impulse response and an amplitude weighting function is applied to the signal. Because the actual channel impulse response length is unknown, the following fact can be remembered. During system design, the length of the channel impulse response has to be investigated. In a MCM system, the guard interval shall be equal or longer than the maximum expected channel impulse response. For this reason, the part (interval with l_I samples, l_I corresponding to the maximum expected channel impulse response, i.e. the guard interval length) of the correlation output signal starting with the first maximum,

$$I_{k0}(n) = r(k_0 + n),\ 0 \le n \le l_I - 1 \qquad \text{(Eq.1)}$$

with k_0 being the position of the first maximum, will be examined to find the best frame start position. The above

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signal part is weighted with the function

$$W(n) = 10^{-\frac{weight\_dB}{10} \cdot \frac{n}{l_I - 1}} \qquad \text{(Eq.2)}$$

The position (n_{max}) of the maximum in the resulting signal interval

$$I_{k0,weighted}(n) = [r(k_0+n)\ W(n)] = [r(k_0+n)\ 10^{-\frac{weight\_dB}{10} \cdot \frac{n}{l_I - 1}}]$$

$$0 \le n \le l_I - 1 \qquad \text{(Eq.3)}$$

will be chosen as best frame start position.

r(k) designates the output signal of the correlator (166) at the time k. The signal is present with a clock frequency which is determined by the multiplication: oversampling factor * subcarrier symbol frequency. The parameter k designates the discrete time in sample clocks. This signal is windowed with information from the threshold unit 168. An interval having the length of l_I values is extracted from the signal r(k). The first value being written into the interval is the correlation start value at the time k_0, at which the output value $r(k_0)$ exceeds the threshold value of the threshold unit 168 for the first time. The interval with the windowed signal is designated by the term $I(k_0)$. The parameter n designates the relative time, i.e. position, of a value inside the interval.

Using the described weighting operation, the earlier correlation maxima are more likely to be chosen as right frame start position. A later coming maximum will only be chosen as frame start position, if the value of the maximum is significantly higher than the earlier one. This operation is applicable especially for MCM, because here it is better to detect the frame start positions some samples too early than some samples too late. Positioning the frame start some samples too early leads to positioning the FFT window a little bit into the guard interval, this contains information of the same MCM symbol and therefore leads to little effects. If the frame start position is detected some samples too late, then the FFT window includes some samples of the following guard interval.

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This leads to a more visible degradation, because the following guard interval contains information of the following MCM symbol (ISI occurs).

It is important to know that the first visible correlation maximum after receiver power-on does not necessarily correspond to the first CIR (channel impulse response) cluster. It is possible that it is corresponding to a later cluster, see Figure 5. For this reason during power-on one should wait for a second frame start before starting demodulation.

It is clear that amplitude determining methods different from the described $alpha_{max+}$ $beta_{min-}$ method can be used. For simplification, it is possible to reduce the amplitude calculation to a detection as to whether the current amplitude is above or below the average amplitude. The output signal then consists of a -1/+1 sequence which will be correlated with a known bit sequence, also in -1/+1 values. This correlation can easily be performed using a simple integrated circuit (IC).

In addition, an oversampling of the signal received at the RF front end can be performed. For example, the received signal can be expressed with two times oversampling.

This oversampled signal is passed to a fast running AGC to eliminate fast channel fluctuations before the amplitude of the signal is calculated. The amplitude information will be hard quantized. Values larger than the mean amplitude, mean amplitude is 1, will be expressed as +1, values smaller than the mean amplitude will be expressed as -1. This -1/+1 signal is passed to the correlator that performs a cross correlation between the quantized signal and the stored ideal amplitude values of the reference symbol:

amp_sto(k) = 2*bin(k/4),
if k = 2(oversampling factor) * 2(interpolation factor) * 1,2,3...92
(92 for 184 reference symbol and interpolation factor 2)
amp_sto(k) = 0, else, k <= 2(oversampling factor) *

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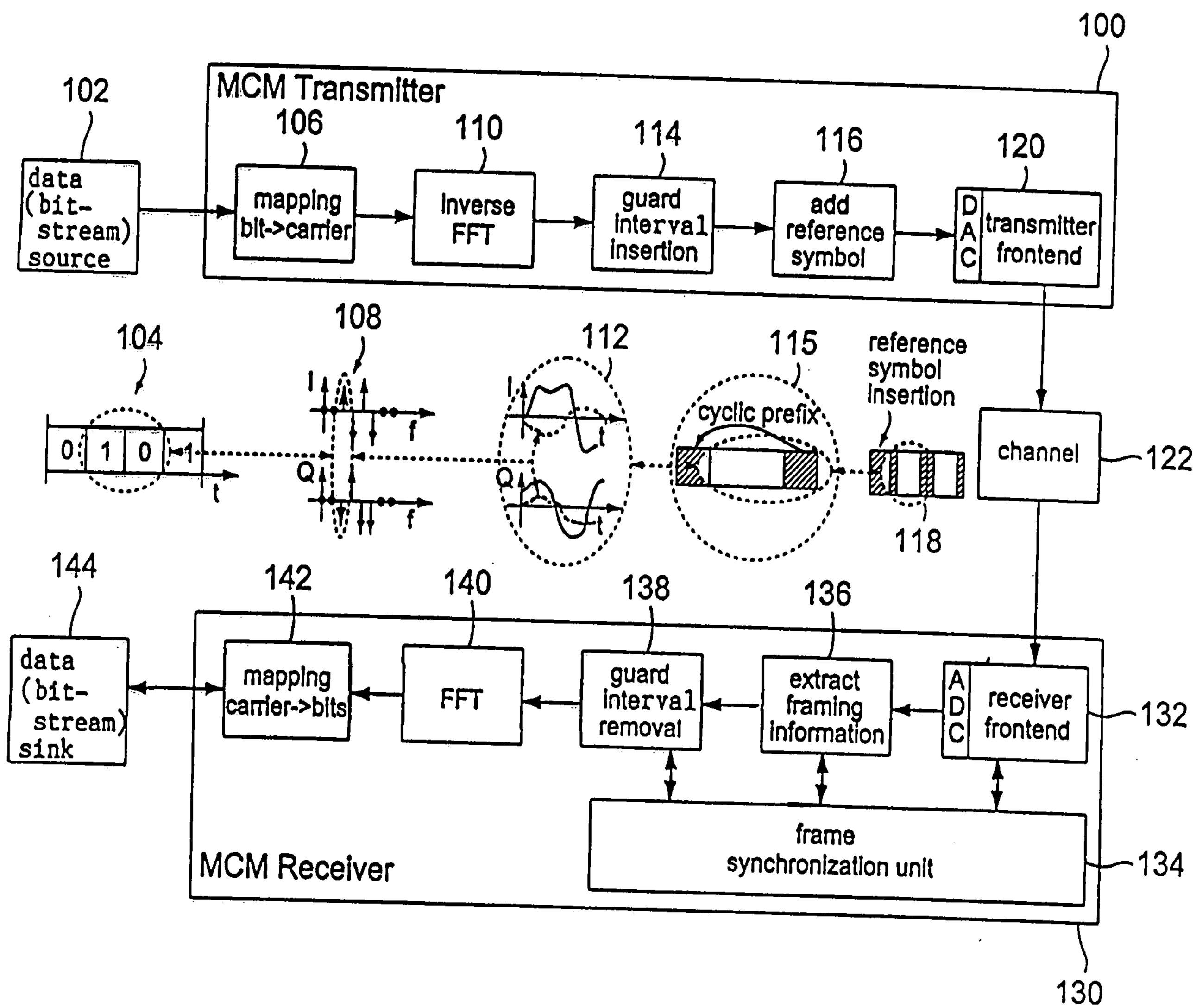

FIG.2

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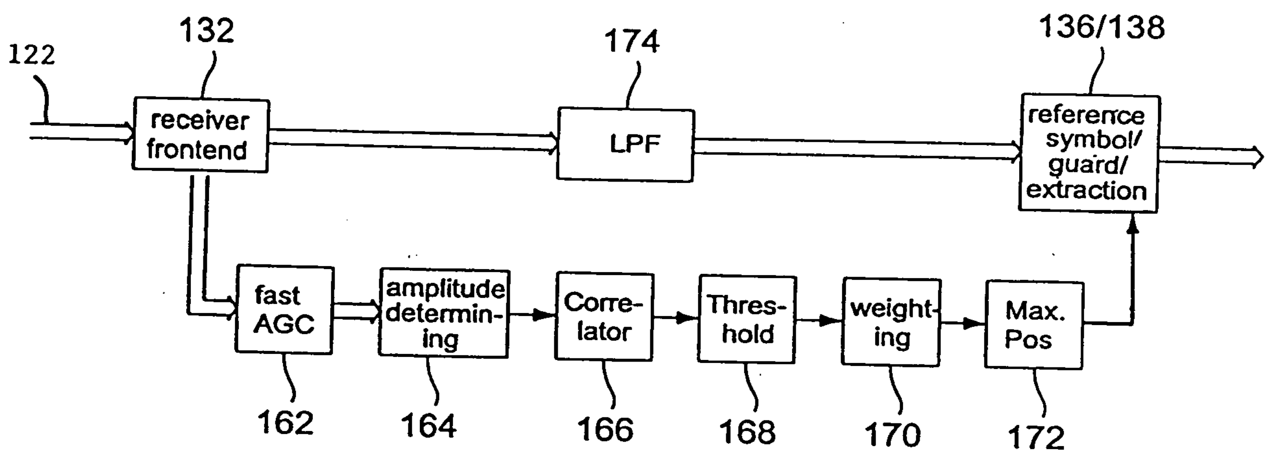
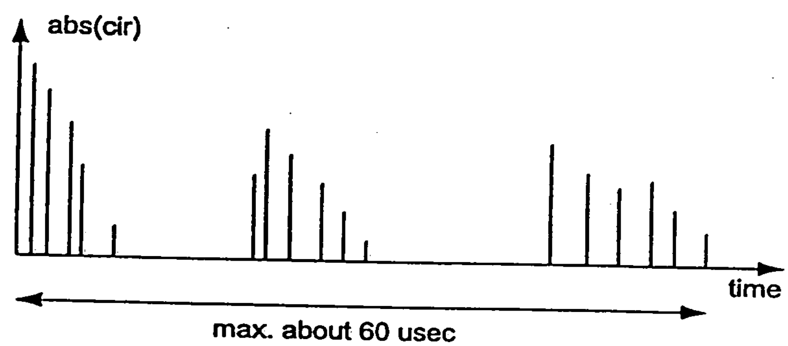


122
132
receiver frontend
174
LPF
136/138
reference symbol/ guard/ extraction
fast AGC
amplitude determin- ing
Corre- lator
Thres- hold
weight- ing
Max. Pos
162
164
166
168
170
172

FIG.4



abs(cir)
time
max. about 60 usec

FIG.5

CLAIMS

1. A method for generating a signal having a frame structure, each frame of said frame structure comprising at least one useful symbol (12), a guard interval (14) associated to said at least one useful symbol (12) and a reference symbol (16), said method comprising the steps of:

   performing an amplitude modulation of a bit sequence, the envelope of the amplitude modulated bit sequence defining the reference pattern of said reference symbol (16); and

   inserting the amplitude modulated bit sequence into said signal as said reference symbol (16).

2. The method according to claim 1, wherein said signal is an orthogonal frequency division multiplexed signal.

3. The method according to claim 1 or 2, wherein said amplitude modulation is performed such that a mean amplitude of said reference symbol (16) substantially corresponds to a mean amplitude of the remaining signal.

4. A method for generating a multi-carrier modulated signal having a frame structure, each frame of said frame structure comprising at least one useful symbol (12), a guard interval (14) associated to said at least one useful symbol (12) and a reference symbol (16), said method comprising the steps of:

   providing a bitstream (104);

   mapping bits of said bitstream (104) to carriers in order to provide a sequence of spectra (108);

   performing an inverse Fourier transform (110) in order to provide multi-carrier modulated symbols (112);

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associating (114) a guard interval to each multi-carrier modulated symbol;

generating said reference symbol (16) by performing an amplitude modulation of a bit sequence, the envelope of the amplitude modulated bit sequence defining the reference pattern of said reference symbol;

associating (116) said reference symbol (16) to a predetermined number of multi-carrier modulated symbols and associated guard intervals in order to define said frame; and

inserting said amplitude modulated bit sequence into said signal as said reference symbol (16).

5. The method according to claim 4, wherein said multi-carrier modulated signal is an orthogonal frequency division multiplex signal.

6. The method according to claim 4 or 5, wherein said amplitude modulation is performed such that a mean amplitude of said reference symbol (16) substantially corresponds to a mean amplitude of the remaining multi-carrier modulated signal.

7. The method according to one of claims 1 to 6, wherein said bit sequence is a pseudo random bit sequence having good autocorrelation characteristics.

8. The method according to one of claims 1 to 7, wherein a number of useful symbols (12) in each frame is defined depending on channel properties of a channel (122) through which the signal or the multi-carrier modulated signal is transmitted.

9. A method for frame synchronization of a signal having a frame structure, each frame of said frame structure comprising at least one useful symbol (12), a guard

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interval (14) associated with said at least one useful symbol (12) and a reference symbol (16), said method comprising the steps of:

receiving said signal;

down-converting said received signal;

performing (164) an amplitude-demodulation of said down-converted signal in order to generate an envelope;

correlating (166) said envelope with a predetermined reference pattern in order to detect the signal reference pattern of said reference symbol (16) in said signal; and

performing said frame synchronization based on the detection of said signal reference pattern.

10. The method according to claim 9, further comprising the step of performing a fast automatic gain control (162) of said received down-converted signal prior to the step of performing said amplitude-demodulation (164).

11. The method according to claim 9 or 10, wherein the step of performing (164) said amplitude-demodulation comprises the step of calculating an amplitude of said signal using the $alpha_{max+}$ $beta_{min-}$ method.

12. The method according to claim 9 or 10, further comprising the steps of sampling respective amplitudes of said received down-converted signal and comparing said sampled amplitudes with a predetermined threshold in order to generate a bit sequence in order to perform said amplitude demodulation.

13. The method according to claim 12, wherein the step of sampling respective amplitudes of said received down-converted signal further comprises the step of performing an over-sampling of said received down-converted

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signal.

14. The method according to any one of claims 9 to 13, further comprising the step of applying a result of the frame synchronization for a frame in said signal to at least one subsequent frame in said signal.

15. A method for frame synchronization of a multi-carrier modulated signal having frame structure, each frame of said frame structure comprising at least one useful symbol (12), a guard interval (14) associated to said at least one useful symbol (12) and a reference symbol (16), said method comprising the steps of:

receiving said multi-carrier modulated signal;

down-converting said received multi-carrier modulated signal;

performing (164) an amplitude-demodulation of said down-converted multi-carrier modulated signal in order to generate an envelope;

correlating (166) said envelope with a predetermined reference pattern in order to detect the signal reference pattern of said reference symbol in said multi-carrier modulated signal;

performing said frame synchronization based on the detection of said signal reference pattern;

extracting (136/138) said reference symbol (16) and said at least one guard interval (14) from said down-converted received multi-carrier modulated signal based on said frame synchronization;

performing (140) a Fourier transform in order to provide a sequence of spectra from said at least one useful symbol;

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de-mapping (142) said sequence of spectra in order to provide a bitstream.

16. The method according to claim 15, further comprising the step of performing (162) a fast automatic gain control of said received down-converted multi-carrier modulated signal prior to the step of performing said amplitude-demodulation.

17. The method according to claim 15 or 16, wherein the step of performing (164) said amplitude-demodulation comprises the step of calculating an amplitude of said multi-carrier modulated signal using the $alpha_{max+}$ $beta_{min-}$ method.

18. The method according to claim 15 or 16, further comprising the steps of sampling respective amplitudes of said received down-converted multi-carrier modulated signal and comparing said sampled amplitudes with a predetermined threshold in order to generate a bit sequence in order to perform said amplitude demodulation.

19. The method according to claim 18, wherein the step of sampling respective amplitudes of said received down-converted multi-carrier modulated signal further comprises the step of performing an over-sampling of said received down-converted multi-carrier modulated signal.

20. The method according to one of claims 15 to 19, further comprising the step of applying a result of the frame synchronization for a frame in said signal to at least one subsequent frame in said multi-carrier modulated signal.

21. The method according to one of claims 9 to 20, further comprising the step of detecting a location of said signal reference pattern based on an occurrence of a maximum of a correlation signal when correlating said envelope with said predetermined reference pattern.

22. The method according to claim 21, further comprising the

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steps of:

weighting a plurality of maxima of said correlation signal such that a maximum occurring first is weighted stronger than any subsequently occurring maximum; and

detecting said location of said signal reference pattern based on the greatest one of said weighted maxima.

23. The method according to claim 22, further comprising the step of:

disabling the step of performing said frame synchronization for a predetermined period of time after having switched-on a receiver (130) performing said method for frame synchronization.

24. An apparatus for generating a signal having a frame structure, each frame of said frame structure comprising at least one useful symbol (12), a guard interval (14) associated to said at least one useful symbol (12) and a reference symbol (14), said apparatus comprising:

an amplitude modulator for performing an amplitude modulation of a bit sequence, the envelope of the amplitude modulated bit sequence defining the reference pattern of said reference symbol (16); and

means for inserting the amplitude modulated bit sequence into said signal as said reference symbol (16).

25. The apparatus according to claim 24, wherein said signal is an orthogonal frequency division multiplexed signal.

26. The apparatus according to claim 24 or 25, wherein a mean amplitude of said reference symbol (16) substantially corresponds to a mean amplitude of the remaining signal.

27. An apparatus for generating a multi-carrier modulated

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signal having a frame structure, each frame of said frame structure comprising at least one useful symbol (12), a guard interval (14) associated to said at least one useful symbol (12) and a reference symbol (16), said apparatus comprising:

means (102) for providing a bitstream (104);

means (106) for mapping bits of said bitstream (104) to carriers in order to provide a sequence of spectra (108);

means (110) for performing an inverse Fourier transform in order to provide multi-carrier modulated symbols (112);

means (114) for associating a guard interval to each multi-carrier modulated symbol;

means for generating said reference symbol (16) comprising an amplitude modulator for performing an amplitude modulation of a bit sequence, the envelope of the amplitude modulated bit sequence defining the reference pattern of said reference symbol (16);

means (116) for associating said reference symbol (16) to a predetermined number of multi-carrier modulated symbols (12) and associated guard intervals (14) in order to define said frame; and

means for inserting the amplitude modulated bit sequence into said signal as said reference symbol (16).

28. The apparatus according to claim 27, wherein said multi-carrier modulated signal is an orthogonal frequency division multiplex signal.

29. The apparatus according to claim 26 or 27, wherein said means for generating said reference symbol (16) performs the amplitude modulation such that a mean amplitude of said reference symbol (16) substantially corresponds to a mean

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amplitude of the remaining multi-carrier modulated signal.

30. The apparatus according to one of claims 24 to 29, wherein said means for generating said reference symbol (16) generates a pseudo random bit sequence having good autocorrelation characteristics as said bit sequence.

31. The apparatus according to one of claims 24 to 30, comprising means for determining a number of useful symbols (12) in each frame depending on channel properties of a channel (122) through which the signal or the multi-carrier modulated signal is transmitted.

32. An apparatus for frame synchronization of a signal having a frame structure, each frame of said frame structure comprising at least one useful symbol (12), a guard interval (14) associated to said at least one useful symbol (12) and a reference symbol (16), said apparatus comprising:

receiving means (132) for receiving said signal;

a down-converter for down-converting said received signal;

an amplitude-demodulator (164) for performing an amplitude demodulation of said down-converted signal in order to generate an envelope;

a correlator (166) for correlating said envelope with a predetermined reference pattern in order to detect the signal reference pattern of said reference symbol (16) in said signal; and

means for performing said frame synchronization based on the detection of said signal reference pattern.

33. The apparatus according to claim 32, further comprising means (162) for performing a fast automatic gain control of said received down-converted signal preceding said

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amplitude-demodulator (164).

34. The apparatus according to claim 32 or 33, wherein said amplitude-demodulator (164) comprises means for calculating an amplitude of said signal using the $alpha_{max}$+ $beta_{min}$-method.

35. The apparatus according to claim 32 or 33, further comprising means for sampling respective amplitudes of said received down-converted signal, wherein said amplitude-demodulator (164) comprises means for comparing said sampled amplitudes with a predetermined threshold in order to generate a bit sequence.

36. The apparatus according to claim 35, wherein said means for sampling comprises means for over-sampling said received down-converted signal.

37. The apparatus according to one of claims 32 to 36, further comprising means for applying a result of the frame synchronization for a frame in said signal to at least one subsequent frame in said signal.

38. An apparatus for frame synchronization of a multi-carrier modulated signal having a frame structure, each frame of said frame structure comprising at least one useful symbol (12), a guard interval (14) associated to said at least one useful symbol (12) and a reference symbol (16), said apparatus comprising:

a receiver (132) for receiving said multi-carrier modulated signal;

a down-converter for down-converting said received multi-carrier modulated signal;

an amplitude-demodulator (164) for performing an amplitude-demodulation of said down-converted multi-carrier modulated signal in order to generate an envelope;

AMENDED SHEET

a correlator (166) for correlating said envelope with a predetermined reference pattern in order to detect the signal reference pattern of said reference symbol (16) in said multi-carrier modulated signal;

means for performing said frame synchronization based on the detection of said signal reference pattern;

means (136/138) for extracting said reference symbol (16) and said at least one guard interval (14) from said down-converted received multi-carrier modulated signal based on said frame synchronization in order to generate said at least one useful symbol;

means (140) for performing a Fourier transform in order to provide a sequence of spectra from said at least one useful symbol; and

means (142) for de-mapping said sequence of spectra in order to provide a bitstream.

39. The apparatus according to claim 38, further comprising means (162) for performing a fast automatic gain control of said received down-converted multi-carrier modulated signal preceding said amplitude-demodulator (164).

40. The apparatus according to claim 38 or 39, wherein said amplitude-demodulator (164) comprises means for calculating an amplitude of said multi-carrier modulated signal using the $alpha_{max+}$ $beta_{min-}$ method.

41. The apparatus according to claim 38 or 39, further comprising means for sampling respective amplitudes of said received down-converted multi-carrier modulated signal, wherein said amplitude-demodulator (164) comprises means for comparing said sampled amplitudes with a predetermined threshold in order to generate a bit sequence.

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42. The apparatus according to claim 41, wherein said means for sampling comprises means for over-sampling said received down-converted multi-carrier modulated signal.

43. The apparatus according to one of claims 38 to 42, further comprising means for applying a result of the frame synchronization for a frame in said multi-carrier modulated signal to at least one subsequent frame in said multi-carrier modulated signal.

44. The apparatus according to one of claims 32 to 43, further comprising means for detecting a location of said signal reference pattern based on an occurrence of a maximum of a correlation signal output of said correlator (166).

45. The apparatus according to claim 44, further comprising means for weighting a plurality of maxima of said correlation signal such that a maximum occurring first is weighted stronger than any subsequently occurring maximum; and

means for detecting said location of said signal reference pattern based on the greatest one of said weighted maxima.

46. The apparatus according to claim 45, further comprising means for disabling said means for performing said frame synchronization for a predetermined period of time after having switched-on a receiver (130) comprising said apparatus for frame synchronization.

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PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

PCT

To:

SCHOPPE & ZIMMERMANN
Attn. Schoppe, F.
Postfach 71 08 67
D-81458 München
GERMANY

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT OR THE DECLARATION

(PCT Rule 44.1)

	Date of mailing *(day/month/year)* 14/01/1999
Applicant's or agent's file reference FH980402PCT	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/EP 98/ 02169	International filing date *(day/month/year)* 14/04/1998
Applicant FRAUHNOFER-GESELLSCHAFT ZUR FÖRDERUNG .....et al.	

1. [X] The applicant is hereby notified that the International Search Report has been established and is transmitted herewith.

   Filing of amendments and statement under Article 19
   The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):

   When? The time limit for filing such amendments is normally 2 months from the date of transmittal of the International Search Report; however, for more details, see the notes on the accompanying sheet.

   Where? Directly to the International Bureau of WIPO
   34, chemin des Colombettes
   1211 Geneva 20, Switzerland
   Fascimile No.: (41-22) 740.14.35

   For more detailed instructions, see the notes on the accompanying sheet.

2. [ ] The applicant is hereby notified that no International Search Report will be established and that the declaration under Article 17(2)(a) to that effect is transmitted herewith.

3. [ ] **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

   [ ] the protest together with the decision thereon has been transmitted to the International Bureau together with the applicants's request to forward the texts of both the protest and the decision thereon to the designated Offices.

   [ ] no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Further action(s):** The applicant is reminded of the following:

   Shortly after **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.

   Within **19 months** from the priority date, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later).

   Within **20 months** from the priority date, the applicant must perform the prescribed acts for entry into the national phase before all designated Offices which have not been elected in the demand or in a later election within 19 months from the priority date or could not be elected because they are not bound by Chapter II.

Name and mailing address of the International Searching Authority	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	René Stolk

Form PCT/ISA/220 (January 1994)

NOTES TO FORM PCT/ISA/220

These Notes are intended to give the basic instructions concerning the filing of amendments under article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the PCT Applicant's Guide, a publication of WIPO.

In these Notes, "Article", "Rule", and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims, description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international pbulication. Furthermore, it should be emphasized that provisional protection is available in some States only.

What parts of the international application may be amended?

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

When? Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

How? Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Administrative Instructions, Section 205(b)).

The amendments must be made in the language in which the international application is to be published.

What documents must/may accompany the amendments?

Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.

NOTES TO FORM PCT/ISA/220 (continued)

The letter must indicate the differences between the claims as filed and the claims as amended. It must, in particular, indicate, in connection with each claim appearing in the international application (it being understood that identical indications concerning several claims may be grouped),whether

(i) the claim is unchanged;

(ii) the claim is cancelled;

(iii) the claim is new;

(iv) the claim replaces one or more claims as filed;

(v) the claim is the result of the division of a claim as filed.

The following examples illustrate the manner in which amendments must be explained in the accompanying letter:

1. [Where originally there were 48 claims and after amendment of some claims there are 51]:
"Claims 1 to 29, 31, 32, 34, 35, 37 to 48 replaced by amended claims bearing the same numbers; claims 30, 33 and 36 unchanged; new claims 49 to 51 added."

2. [Where originally there were 15 claims and after amendment of all claims there are 11]:
"Claims 1 to 15 replaced by amended claims 1 to 11."

3. [Where originally there were 14 claims and the amendments consist in cancelling some claims and in adding new claims]:
"Claims 1 to 6 and 14 unchanged; claims 7 to 13 cancelled; new claims 15, 16 and 17 added." or
"Claims 7 to 13 cancelled; new claims 15, 16 and 17 added; all other claims unchanged."

4. [Where various kinds of amendments are made]:
"Claims 1-10 unchanged; claims 11 to 13, 18 and 19 cancelled; claims 14, 15 and 16 replaced by amended claim 14; claim 17 subdivided into amended claims 15, 16 and 17; new claims 20 and 21 added."

"Statement under article 19(1)" (Rule 46.4)

The amendments may be accompanied by a statement explaining the amendments and indicating any impact that such amendments might have on the description and the drawings (which cannot be amended under Article 19(1)).

The statement will be published with the international application and the amended claims.

It must be in the language in which the international appplication is to be published.

It must be brief, not exceeding 500 words if in English or if translated into English.

It should not be confused with and does not replace the letter indicating the differences between the claims as filed and as amended. It must be filed on a separate sheet and must be identified as such by a heading, preferably by using the words "Statement under Article 19(1)."

It may not contain any disparaging comments on the international search report or the relevance of citations contained in that report. Reference to citations, relevant to a given claim, contained in the international search report may be made only in connection with an amendment of that claim.

Consequence if a demand for international preliminary examination has already been filed

If, at the time of filing any amendments under Article 19, a demand for international preliminary examination has already been submitted, the applicant must preferably, at the same time of filing the amendments with the International Bureau, also file a copy of such amendments with the International Preliminary Examining Authority (see Rule 62.2(a), first sentence).

Consequence with regard to translation of the international application for entry into the national phase

The applicant's attention is drawn to the fact that, where upon entry into the national phase, a translation of the claims as amended under Article 19 may have to be furnished to the designated/elected Offices, instead of, or in addition to, the translation of the claims as filed.

For further details on the requirements of each designated/elected Office, see Volume II of the PCT Applicant's Guide.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
FH980402PCT		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/EP 98/02169	14/04/1998	

Applicant

FRAUHNOFER-GESELLSCHAFT ZUR FÖRDERUNG .....et al.

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. [ ] **Certain claims were found unsearchable** (see Box I).

2. [ ] **Unity of invention is lacking** (see Box II).

3. [ ] The international application contains disclosure of a **nucleotide and/or amino acid sequence listing** and the international search was carried out on the basis of the sequence listing
   - [ ] filed with the international application.
   - [ ] furnished by the applicant separately from the international application,
     - [ ] but not accompanied by a statement to the effect that it did not include matter going beyond the disclosure in the international application as filed.
   - [ ] Transcribed by this Authority

4. With regard to the **title**,
   - [ ] the text is approved as submitted by the applicant
   - [X] the text has been established by this Authority to read as follows:

   COARSE FREQUENCY SYNCHRONISATION IN MULTICARRIER SYSTEMS

5. With regard to the **abstract**,
   - [X] the text is approved as submitted by the applicant
   - [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this International Search Report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is:

   Figure No. 2
   - [ ] as suggested by the applicant.
   - [ ] because the applicant failed to suggest a figure.
   - [X] because this figure better characterizes the invention.
   - [ ] None of the figures.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 98/02169

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04L27/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 631 406 A (FRANCE TELECOM; TELEDIFFUSION DE FRANCE) 28 December 1994 see page 3, line 27 - line 28 ---	1-7,9, 15, 24-30, 32,38
A	WO 98 00946 A (LELAND STANFORD JUNIOR UNIVERSITY) 8 January 1998 see page 17, line 16 - line 22 see page 26, line 17 - page 27, line 2 see page 27, line 14 - line 24 see page 28, line 4 - line 16 --- -/--	1,4,9, 15,24, 27,32,38

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 January 1999	14/01/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Scriven, P

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Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	MOOSE: "A technique for orthogonal frequency division multiplexing frequency offset correction" IEEE TRANSACTIONS ON COMMUNICATIONS., vol. 42, no. 10, October 1994, pages 2908-2914, XP002019915 NEW YORK, US cited in the application see page 2908, right-hand column, paragraph 5 see page 2911, right-hand column, paragraph 5 - page 2912, right-hand column, paragraph 2 ---	1,4,9, 15,24, 27,32,38
A	KELLER; HANZO: "Orthogonal frequency division muliplex synchronisation techniques for wireless local area networks" IEEE INTERNATIONAL SYMPOSIUM ON PERSONAL, INDOOR AND MOBILE RADIO COMMUNICATIONS, 15 October 1996, pages 963-967, XP002063294 New York, US see page 963, right-hand column, paragraph 3 ---	1,4,9, 15,24, 27,32,38
A	PALACHERLA: "DSP- P routine computes magnitude" EDN ELECTRICAL DESIGN NEWSW, vol. 34, no. 22, 26 October 1989, pages 225-226, XP000070840 NEWTON, MASSACHUSETTS, US see the whole document -----	11,12, 40,41

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 98/02169

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0631406 A	28-12-1994	FR 2707064 A	30-12-1994
WO 9800946 A	08-01-1998	US 5732113 A	24-03-1998

Form PCT/ISA/210 (patent family annex) (July 1992)